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CP Rail Toronto Yard Noise Study

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CP Rail Toronto Yard Noise Study

by

Mr. G.L. Walker

Planning & Analysis Department

CPRail, Toronto, Ontario.

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May 31, 1985.

The contents of this report reflect the views of the author and not necessarily the official views or policies of the Transportation Development Centre of Transport Canada.

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17 Abstract

During the period January-to-July, 1985, research was conducted with the purpose of reducing the squeal produced by the operation of car retarders within railway hump yards through the application of a coating of weld material to the contact surface of the retarder brake shoes. This research, funded jointly by CP Rail and Transport Canada, was initiated at the request of a Special Committee within the Municipality of Scarborough. The project involved both laboratory research and field experiments. In the laboratory, samples of railway wheel material were rotated against samples of retarder brake shoe material that had been coated with a weld material. Eight test shoes were then coated with a weld material that showed promising results in the laboratory, and installed on the master retarder at CP Rail's Toronto Yard in Agincourt. Vibration readings were then taken to determine resulting noise reduction. Based on the criteria of noise reduction, retardation capabilities, and overall cost effectiveness (wear rate and cost of material), the weld material known commercially as Fluxofil 58 was determined to produce the best results. The recommendation of the report is that CP Rail equip its complete master retarder with brake shoes coated with Fluxofil 58.

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17 Résumé

Ce rapport décrit la recherche faite de janvier à juillet 1985 sur la possibilité de réduire les bruits engendrés par les freins de voie dans les gares de triage en étudiant l'effet du rechargement (remise en état par soudage) des sabots-cales. Cette recherche, financée conjointement par CP Rail et Transports Canada, avait été lancée à la demande d'un comité spécialement mis sur pied par la municipalité de Scarborough. La recherche a été faite à deux niveaux: en laboratoire et in situ. En laboratoire, un montage a été utilisé où des éprouvettes prélevées de roues de wagons ont été frottées contre des éprouvettes de sabots-cales rechargées d'un produit d'apport déterminé. Ensuite, huit sabots-cales ont été rechargés du produit d'apport qui avait donné les meilleurs résultats en laboratoire, et posés sur le frein de voie primaire de la gare de triage de CP Rail à Agincourt. Les niveaux acoustiques ont été mesurés. En se fondant sur les paramètres d'atténuation des bruits, d'effet sur le freinage et du rapport avantage-coût (rapport du taux d'usure au coût de rechargement), il a été déterminé que le produit d'apport connu sur le marché sous le nom de Fluxofil 58 produisait les meilleurs résultats. Le rapport recommande à CP Rail d'équiper son frein de voie primaire de sabots-cales rechargés de ce produit.

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EXECUTIVE SUMMARY

The purpose of this study is to fully investigate the method established by the Missouri Pacific Railway (MoPac) to rebuild retarder brake shoes with weld material, for the purpose of determining the feasibility of using this technique to reduce the noise produced by the retarders at CP Rail's Toronto Yard. In establishing this procedure, MoPac was attempting to reduce their retarder maintenance costs; however, they discovered that as a by-product of their efforts, the noise generated by the retarder was significantly reduced. It was the possibility that this noise reduction could be duplicated, or, indeed, improved upon, that initiated this study.

Two interdependent approaches were used to investigate the effect of rebuilt brake shoes on retarder squeal. Brake shoes were first rebuilt according to the MoPac method and these were installed on the master retarder at Toronto Yard. Observed results from laboratory research into the metallurgical aspects of retarder squeal were then used to direct the field testing towards alternative weld materials and application methodologies. The various materials were evaluated according to their noise reduction capabilities, effect on retardation, wear life and cost of rebuilding.

The MoPac methodology was successfully duplicated. It is concluded that the rebuilt shoes reduced the vibration levels by ninety percent. However, the MoPac material was found to be unsatisfactory due to its rapid wear rate, and excessive cost. Also, this material precipitated severe vibration in the retarder beam, this probably leading to extreme wear of the retarder over time.

Various alternative weld materials were then examined in the laboratory. Fluxofil 58 was found to be the one that best met the selection criteria.

A field test was established with shoes rebuilt using the Fluxofil material. The results have been very encouraging. There are indications that the number of cars squealing is reduced by eighty percent. These rebuilt shoes appear to wear at a rate no faster than regular shoes. The cost to rebuild shoes with Fluxofil 58 is comparable to the price of new regular shoes. The severe horizontal vibration is virtually eliminated with the Fluxofil material.

The experimentation to date has still left some questions unanswered, however. Since the field test only encompassed eight of the approximately one hundred shoes on the master retarder, we cannot draw any conclusions about the effect of the rebuilt shoes on retardation. Also, the wear life estimates of the rebuilt shoes are based on a relatively short period of observation. A more extensive field test of longer duration is required to satisfactorily answer these questions.

In view of the encouraging results to date, and the still-unanswered questions, we recommend that the following steps be taken:

1. The complete master retarder be equipped with shoes rebuilt with Fluxofil 58. This installation should be phased in over a period of approximately ten weeks, with expected completion in mid-August. CP Rail is to observe the wear rate and retardation capabilities, and prepare a full report by September 30, 1985.

2. Dependent on the success of #1, above, the brake shoes on the group retarders should be replaced with Fluxofil-rebuilt shoes during the latter part of 1985 and early 1986.

Office of Manager,
Planning & Analysis,
CP Rail.

Toronto, May 31, 1985.

SOMMAIRE

Ce rapport rend compte de la recherche concernant la méthode de rechargement des sabots-cales étudiée par la Missouri Pacific Railway (MoPac). Il s'agissait de vérifier à quel point cette technique permettait de réduire les bruits engendrés par les freins de voie dans la gare de triage du CP à Toronto. La méthode MoPac découle de la recherche que cette compagnie faisait sur les moyens de réduire les coûts d'entretien des freins de voie, celle-ci ayant remarqué par hasard que les bruits produits par les freins de voie étaient sensiblement réduits. La présente étude a donc reçu pour objectif d'étudier la possibilité d'appliquer cette méthode ailleurs, en l'améliorant, si possible.

Deux approches parallèles ont été suivies, visant toutes deux à étudier l'effet du rechargement des sabots-cales sur les bruits engendrés par les freins de voie. Tout d'abord, le rechargement des sabots-cales a été fait selon la méthode MoPac, suivi de leur installation sur les freins de voie primaires de la gare de triage. Parallèlement, une recherche de laboratoire a été faite sur les causes métallurgiques des bruits, et dont le résultat, appliqué aux essais in situ, a servi à caractériser les produits d'apport utilisés et les méthodes de rechargement mises en oeuvre. Les paramètres pris en compte ont été le degré d'atténuation des bruits, l'effet sur le freinage, la résistance à l'usure et le coût de rechargement.

Le bien-fondé de la méthode MoPac a pu être ainsi vérifié, une réduction de 90 p. cent des niveaux vibratoires ayant été observée. Par contre, le produit d'apport utilisé par MoPac a été trouvé peu satisfaisant à cause de sa faible résistance à l'usure et de son coût excessif, et aussi parce qu'il engendrait de fortes vibrations dans le support du frein de voie, ce qui devrait entraîner une usure inacceptable des freins avec le temps.

Des divers produits d'apport essayés en laboratoire, c'est le Fluxofil 58, qui a satisfait le mieux aux critères de sélection établis.

Les essais in situ utilisant le Fluxofil ont été encourageants. Le nombre des wagons ayant engendré un grincement des freins de voie a chuté de 80 p. cent, la résistance à l'usure semble être égale à celle des sabots standard et, enfin, le coût du sabot rechargé se compare à celui du sabot neuf. Quant aux fortes vibrations horizontales, elles ont été pratiquement éliminées.

Etant donné que, de la centaine de sabots-cales composant le frein de voie primaire, huit seulement ont été rechargés selon la méthode étudiée, les expériementations faites ne peuvent pas être considérées comme tout à fait concluantes, plusieurs questions restant encore à élucider. D'autant plus que les observations faites sur la résistance à l'usure n'ont porté que sur un bref laps de temps. Il faudra donc attendre le résultat d'essais in situ plus étendus dans l'espace et dans le temps avant de pouvoir répondre aux questions en suspens.

Dans ces circonstances, nous formulons les recommendations suivantes:

1. Recharger de Fluxofil 58 tous les sabots-cales du frein de voie primaire, sur une période d'une dizaine de semaines, de manière à terminer le travail vers la mi-août. CP Rail procédera alors à des observations sur l'effet de ce produit sur la résistance à l'usure et sur l'efficacité du freinage, un rapport détaillé étant prévu pour le 30 septembre 1985.

2. Si les résultats sont probants, procéder à l'installation de sabots-cales rechargés de Fluxofil 58 sur l'ensemble des freins secondaires, ce travail devant se faire en 1985 et au début de 1986.

Chef, Planification et Analyse

Toronto, le 31 mai 1985

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   D: Dr. J.A. Schey - Report 2 - May 12, 1985.

INTRODUCTION

In this report we present the results and recommendations arising from a project to investigate the viability of using rebuilt brake shoes on the master and group retarders in Toronto Yard. This research project, jointly funded by CP Rail and Transport Canada, arises out of a commitment by CP Rail to the City of Scarborough to further investigate the effectiveness of rebuilt retarder brake shoes in reducing the noise created by their operation. This work forms part of CP Rail's participation in the City of Scarborough's Special Committee of the Building Fire and Legislation Committee whose mandate is to recommend means for reducing the noise generated by railway operations within the CP Rail Agincourt Yard.

The purpose of the research project is to examine the overall effectiveness of rebuilt brake shoes. Various welding materials and application methodologies are to be evaluated according to the criteria:

- noise reduction;
- retardation capabilities;
- wear life; and
- cost of rebuilding.

The study was conducted in two interdependent segments. First, field experiments were conducted in which rebuilt shoes were actually installed on the master retarder at Toronto Yard, and their effectiveness evaluated according to the above criteria. The second segment involved the laboratory testing of various welding materials for the purposes of examining the metallurgical characteristics of the squeal phenomenon and of recommending alternative materials for investigation in the field experiments.

The project has involved many players all of whose contributions were vital to its success. Dr. J.A.Schey, of the Waterloo Research Institute, conducted the laboratory research. Mr. J.E. Coulter, of Barman, Coulter, Swallow Associates conducted all the noise measurements for the field experiments, and provided the necessary interpretations and conclusions. Mr. J.C. Swallow, also of BCS Associates, assisted with the establishment of the laboratory experimentation and provided helpful interpretations of the laboratory results in terms of field experience. Mr. L.C. Groves, of Crothers Limited, was very helpful in arranging for all the welding of shoes and laboratory samples, as well as suggesting alternative weld materials for investigation. Mr. K.S. Young, of CP Rail, arranged for the installation of all field test shoes and equipment, as well as providing the field observations for rebuilt shoe wear.

In the following sections, we shall examine separately each segment of the project in detail, and then the overall project conclusions and recommendations.

2. Toronto Yard Experiment

2.1 Objectives:

The objectives of this experiment are to duplicate the technique used by the Missouri Pacific Railway (MoPac) to rebuild retarder brake shoes with weld material , establish a field testing procedure to evaluate the overall effectiveness of the MoPac technique, and then to improve upon it.

Various welding materials and application methodologies are to be examined. These are to be evaluated according to the following criteria:

- noise reduction characteristics;
- retardation capabilities;
- wear rate;
- cost of rebuilding the brake shoes.

2.2 Phase I - Eutectic Welding Material

Procedure:

A set of eight brake shoes was rebuilt exactly in the same manner as that used by MoPac. The welding materials, Eutectic 2222 and Eutectic 6868 were applied in alternating four-inch pad sections, separated by half-inch gaps. The material was applied manually from a welding rod.

On January 28, 1985, the eight test shoes were installed at the top of the lower half of the master retarder, four shoes on each side of the south rail. The location of the test shoes was so chosen in order that the vibration recording equipment would be able to detect the movement of cars from the upper half to the lower half of the retarder. This permits the association of vibration levels to the location of the car as it passes through the retarder.

A miniature accelerometer was then installed on one of the test shoes, and the vibration pattern monitored for all cars passing through the master retarder during a period of nine weeks.

Observations:

The results of the vibration measurements and their interpretation are summarized in the February 14, 1985, report by Mr. J.E. Coulter, shown in Appendix A. It is estimated that approximately virtually all cars passing through the master retarder either did not squeal at all or entered the test section squealing and had the squeal squelched therein.

The retarder beam experienced extreme horizontal vibration for the first two weeks after installation of the test shoes. The phenomenon was described as "chatter". We theorize that this vibration was due to the rough surface on the rebuilt retarder shoes, and that the "chatter"

subsided only when the surface had been ground smooth through the retardation of many cars. Prolonged horizontal vibration of the observed magnitude would definitely result in long-term damage to the retarder, itself.

The weld surface displayed a rapid and uneven wear rate. The horizontally bevelled wear pattern indicated extreme adhesion taking place between the weld material and wheel surfaces. The observed wear rate was especially rapid on the outside shoes.

The Eutectic weld material is very expensive. It is estimated that the production cost would be approximately $600 per shoe.

Conclusions:

We conclude that the rebuilding procedure shows strong potential for reducing the squeal produced by the retardation process. However, the Eutectic material is not satisfactory for use as the rebuilding material for the following reasons:

1. The horizontal vibration exhibitted by the retarder beam would result in long-term damage to the retarder.
2. The observed uneven and rapid wear rate would result in too short a wear life.
3. The estimated cost per shoe is approximately $600. This, coupled with the short wear life, seriously reduces the cost-effectiveness of using this material.

2.3 Phase II - Fluxofil Welding Material

Procedure:

The above experimental procedure was duplicated with Fluxofil 58 weld material. Fluxofil 58 was identified in the metallurgical research segment of the project, described in detail in Section 3, below, as a promising candidate for the rebuilding material. Initially, as above, the weld material was applied manually from welding rod in a pattern consisting of four-inch pad sections separated by half-inch gaps.

Eight test shoes were installed in the same location on the master retarder as in the Phase I test. Vibration measurements were taken and wear rates were observed as in Phase I.

After three weeks of testing, the gaps in the weld pattern were filled in with weld material and further vibration measurements taken.

Observations:

The observed effectiveness of these test shoes in reducing the noise produced is summarized in Mr. Coulter's letter of May 1, shown in Appendix B. It is estimated that the number of cars squealing is reduced by eighty percent as a result of this rebuilding procedure.

The wear rate observed for the Fluxofil test shoes is considerably improved over that observed with the Eutectic shoes. Fluxofil has a hardness rating of HRC 61, more than twice that for the steel used in the retarder brake shoes, themselves. (Wear life is closely related to hardness.) Preliminary measurements of the wear life of the test shoes indicate that rebuilt shoes should last at least as long as regular shoes. It must be stressed, however, that these measurements are based only on a five-week observation period and that a test period of longer duration is required in order to obtain more reliable estimates of wear life.

There is much less evidence of a horizontally bevelled wear pattern in the Fluxofil shoes. This tends to indicate much less adhesion between the wheel and weld materials.

There was some horizontal vibration of the retarder beam with initial installation. This reduced significantly with wear of the shoes over time, and also with the filling in of the gaps between the weld pads.

While the final cost cannot be determined until a production process is established, it appears that the price of the Fluxofil weld material makes it possible for the brake shoes to be rebuilt at a cost that is quite comparable to the purchase price of new regular shoes.

Conclusions:

We conclude that Fluxofil 58 provides a cost effective material to be used for the rebuilding of retarder brake shoes. The test shoes have reduced the number of squeals by approximately eighty percent. Preliminary indications are that shoes can be rebuilt at reasonable cost and will wear at least as long as regular brake shoes.

Due to the small number of shoes used,it is not possible to draw reliable conclusions from this experiment regarding the retardation capabilities of the rebuilt shoes. However, the metallurgy research segment of this project, described in detail below, has shown that the coefficient of friction for Fluxofil 58 is approximately 0.4 - 0.55. This is similar to that for regular brake shoe steel, and is very close to the dry friction value of 0.5. A larger scale field test is required in order to assess the effect of Fluxofil 58 on retardation with more certainty.

Finally, we conclude that the gaps in the welding pattern have no effect on the noise reduction characteristics of the rebuilt shoes and that there is no need to keep the gaps in the rebuilding pattern specification.

3. Metallurgy Research

3.1 Objectives

The objective of this portion of the project is to identify welding materials suitable for application to retarder brake shoes. The results from this research are intended to provide input to the field experimentation segment by recommending alternative welding materials for examination.

This research is to examine the squeal phenomenon, and identify as much as possible, the effect of certain metallurgical characteristics of the two contacting materials on squeal reduction.

Finally, this research should provide indications of the relative wear life of the welding materials that are investigated.

3.2 Procedure:

Dr. J.A. Schey of the Mechanical Engineering Department of the University of Waterloo conducted the experimentation in this segment of the study. Dr. Schey worked closely with Mr. L.C. Groves, Shop Manager of the Toronto Welding Shop of Crothers Limited, in choosing potential welding materials for investigation.

Samples of railway wheel and retarder brake shoe material were provided by CP Rail for the purposes of the laboratory experimentation. Specially designed laboratory machinery applied the wheel sample to the brake shoe sample at preset pressure of one thousand pounds per square inch, and then rotated same at preset speed of six revolutions per minute (twenty linear inches per minute).

The results were interpreted through visible inspection of the amount of weld material "picked up" by the wheel material, and by graphs of the torque force. Suitable materials would show low tendency for "pick-up", and relatively steady torque through the duration of the experiment.

Other factors used for the evaluation of the various welding materials include:

- Pick-up: A surface that shows little pick-up indicates low tendency to adhere to the wheel surface. Low pick-up is the key indicator of expected noise reduction characteristics.
- Hardness: Harder materials should show less tendency toward adhesion, and longer wear life.
- Coefficient of Friction: A coefficient value of approximately 0.5 should provide satisfactory friction between two dry surfaces, and hence should result in satisfactory retardation capabilities.

- Vibration: The vibration measurement is a subjective interpretation of the uniformity of torque as a result of the rotation under pressure. A steady torque trace indicates relative absence of "stick-slip".

3.3 Observations:

The complete account of observations and conclusions is presented in Dr. Schey's reports of March 19 and May 12, 1985, shown as Appendices C and D, below.

We summarize the principal observations as follows:

1. Eutectic Welding Materials:

MoPac used the weld materials, Eutectic 2222 and Eutectic 6868 in their rebuilt shoes. For this reason, these were the first materials examined in the laboratory.

Eutectic 2222 was found to be a very soft material, registering a reading of HRB 86. This resulted in very rapid and heavy pick-up of weld material by the wheel samples.

Eutectic 6868, approximately of the same hardness, also showed tendency toward heavy pick-up. 2. Materials Rejected:

The following is a list of materials examined in the laboratory and rejected principally for the reasons shown:

Stoody 105 - severe and rapid pick-up;
Vertamatic 922 - immediate welding to the wheel sample;
Stoody 102 - heavy pick-up;
Stoody 103 - soft specimen: heavy pick-up;
- hard specimen: coefficient of friction too low;
Stoody 4552 - very heavy pick-up;
Teledyne 258 s - very heavy pick-up;

3. Materials Recommended:

The laboratory experimentation has indicated the following four welding materials as viable candidates for rebuilding the retarder brake shoes.

Haynes 25: This material is a soft material (HRB 96) containing a high percentage of Nickel and Chromium. The material has a coefficient of friction of 0.4. The material displayed a tendency for very light pick-up.

Fluxofil 58: With a hardness reading of HRC61, this material is harder than the steel used for regular brake shoes. The material has a relatively high percentage of Carbon in its composition. Its coefficient of friction ranges from 0.4 to 0.55. The material displayed tendency a for light pick-up and an essentially steady torque trace.

Harfac 6: This material has a relatively high percentage composition of Cobalt-Chromium-Tungsten, a hardness reading of HRC 32-39, and a coefficient of friction of 0.35-0.4. It displayed a tendency for very light pick-up to the wheel material.

Teledyne 255 S: This material has a hardness reading of HRC 46-55 and coefficient of friction of 0.3-0.6. Its composition is high in Chromium. The material displayed a tendency for very light pick-up. The material also tended to crack during experimentation.

3.4 Conclusions:

The metallurgy research has confirmed that adhesion is the key to the production of the squeal in the retarder process. Adhesion occurs when there is dry welding between the two surfaces in contact. The squeal is generated by the continual instantaneous welding and releasing of the two materials; this phenomenon is also referred to as "stick-slip". This adhesion is manifested in the laboratory experiments by the "pick-up" of weld material by the wheel sample. Experimentation has revealed that the degree of adhesion that occurs depends on both the composition and hardness of the weld material. It is concluded that adhesion is reduced by:

- the hardness of the weld material being at least HRC 58, and/or

- the weld material having a relatively high percentage composition of Nickel, Cobalt or Chromium.

The Eutectic materials have proven unsatisfactory in the laboratory. Eutectic 2222 was found to be too soft, and resulted in heavy adhesion properties. While Eutectic 6868 appeared to resist adhesion satisfactorily, it too was found to be too soft, and hence would lead to a short wear life.

Of the materials recommended by the research, the Haynes, Harfac and Teledyne materials were not further investigated in the field experimentation for the following reasons. Harfac 6 registered a very low coefficient of friction, and Teledyne 255-S displayed a tendency to crack under laboratory conditions, both of these conditions raising concerns about the retardation capabilities of these materials. The Haynes and Harfac materials are both relatively expensive, due to their high relative compositions of Chromium and Cobalt.

Fluxofil 58 was found to best meet all selection criteria. Fluxofil 58, a material that is reasonable in expense and readily available, demonstrated minimal pick-up characteristics, steady torque trace and satisfactory coefficient of friction.

4. Conclusions:

We conclude that the rebuilding of brake shoes with weld material is a viable method for the reduction of squeal produced by retarders. This is supported by the observed results in both the field experimentation and the laboratory research. We have taken the methodology originally established by MoPac and improved upon it by changing both the weld material and the application pattern. Finally the process has been made cost effective through the use of welding materials and facilities suitable for mass production of the rebuilt shoes

The study has taught us much about the squeal process. Having examined various materials and application patterns, we conclude that the material used in the rebuilding process, rather than the application pattern, is the key determining factor. The reduction of squeal depends on both the composition and the hardness of the material in contact with the railway wheel. Materials with hardness coefficients of at least HRC 57, and/or which have relatively high percentage compositions of Cobalt, Chromium or Nickel tend to reduce the incidence of squeal.

The Eutectic weld material used by MoPac has been found to be unsatisfactory. While it showed some success in reducing the amount of noise produced by the retarder, its rapid wear life and high production cost make the material unacceptable. Also, shoes rebuilt with Eutectic materials tended to precipitate a severe horizontal vibration ("chatter") in the retarder beam, raising concerns about serious long-term wear of the retarder, itself.

Fluxofil 58 appears to be a viable weld material for the rebuilding of the brake shoes. Its performance in the field experimentation indicates that it will result in an eighty percent reduction in the number of cars squealling. Preliminary indications are that shoes can be rebuilt with Fluxofil 58 at reasonable cost, and that they will then wear at least as long as regular shoes. With coefficient of friction approximately 0.5, we do not expect shoes rebuilt with Fluxofil to have an adverse effect on retardation capabilities.

5. Recommendations:

We recommend the following steps be taken:

1. The master retarder be fully equipped with shoes rebuilt with Fluxofil 58. The installation of these shoes should be phased in in five batches of twenty shoes each, with a time delay of approximately two weeks between phases. Tentative schedule for installation is June 24 to August 19.

2. CP Rail is to accurately measure the wear life and retardation capabilities of the rebuilt shoes, and prepare a full report by September 30, 1985.

3. Based on the success of the rebuilt shoes on the master retarder, CP Rail is to commence a program of replacing all shoes on the group retarders in the latter part of 1985 and early 1986.

Office of the Manager,
Planning & Analysis
May 31, 1985.

APPENDIX A

J.E. Coulter - Report 1 - February 14, 1985

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February 14, 1985

CP Rail
Room O-108,
Union Station,
Toronto, Ontario
M5J 1E8

Attention: Gary Walker, Manager of Planning and Analysis Region

RE: CP Retarder Retrofit Noise Test

Gentlemen:

At the request of Mr. Gary Walker of CP Rail, Barman Coulter Swallow Associates has carried out measurements of the vibration of the rewelded master retarder brake shoes at the Agincourt Yard.

One of the eight rewelded retarder shoes was fitted with a miniature accelerometer (see Fig.1 & 2) and the vibration above 2500 Hz monitored via chart recorder several days for each car passby (several thousand events). The data was compared to similar data taken in August of 1984. In the August measurements the vibration levels during squeal were often 300 g (3000 meters/sec^2) and greater. In the February 1985 rewelded shoe measurements, the vibration levels were approximately 10% of this value while the wheels were in contact with the rewelded section. There is also evidence of the high squeal vibration levels in the data before the car reached the rewelded section (see Fig.3 & 4). These high levels were always squelched when the car wheels reached the rewelded section. Our conclusion is that the rewelded section is not squealling.

There is significant lower frequency horizontal vibration in the beam which was measured with a standard accelerometer mounted horizontally on the back of the retarder beam (see Fig.1 & 2). There are two frequencies involved; one at 60 Hz with a peak acceleration of 3g (30 meters/sec^2) and one at 30 Hz with a peak acceleration of 1.8g (18m/sec^2)(see Fig.5). These frequencies appear related to the rate at which the wheel comes into contact with the welded pads (60 Hz) and to a phenomenum relating to every second pad (30 Hz). As the weld material changes every second

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pad, there may be some change in properties from one weld material to the next or perhaps the 2 materials are wearing at a different rate.

The dynamic bearing load due to the vibration may be significant. It appears to be a significant fraction of the static load. Therefore, measures to reduce the vibration should be considered in the final design of rebuilt retarder shoes which would also incorporate Dr. Schey's findings on metalurgical details.

The wear on the outside shoe pads is not even. Every other pad (i.e one particular type of welding material) is warn with a significant vertical bevel (see Fig.6). The pads between the bevelled ones are warn evently but may be wearing faster. Holes have been drilled in the shoes and the depth measured for comparison at a later date to determine the wear rate. The inside shoes appear to be wearing more evenly.

Except for a final wear rate determination, we believe that the data taken to date is sufficient to determine that the rewelded brake shoes are effective against squeal and that no further measurements are required on these shoes with regard to this aspect of their performance.

We trust the above will assist in your deliberations. Please do not hesitate to contact the undersigned should there be any questions.

Yours truly,
BARMAN COULTER SWALLOW ASSOCIATES

J. E. Coulter

John E. Coulter, B.A.Sc., P.Eng.
JEC/ss

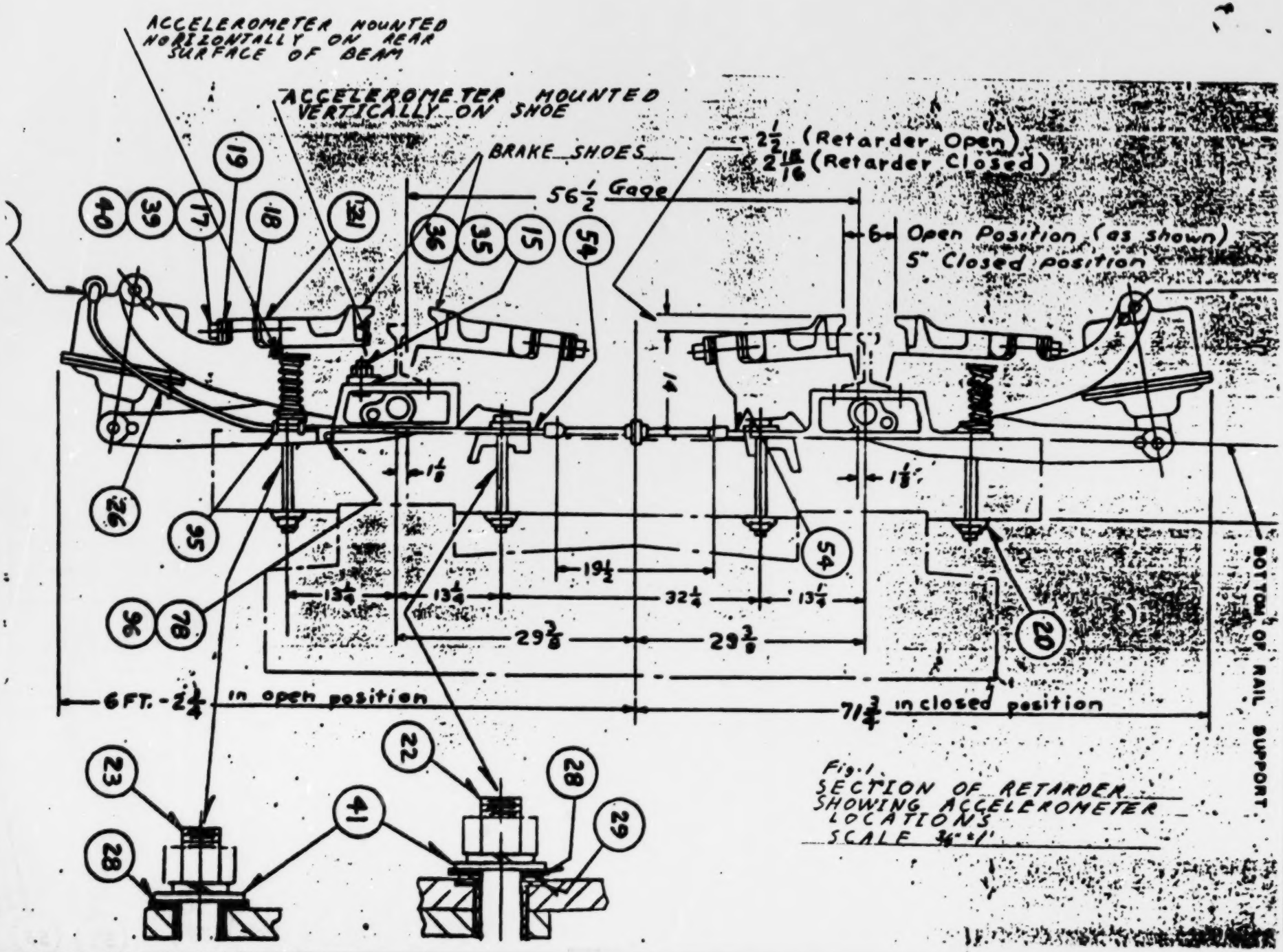


Fig. 1
SECTION OF RETARDER SHOWING ACCELEROMETER LOCATIONS
SCALE 3/4" = 1'

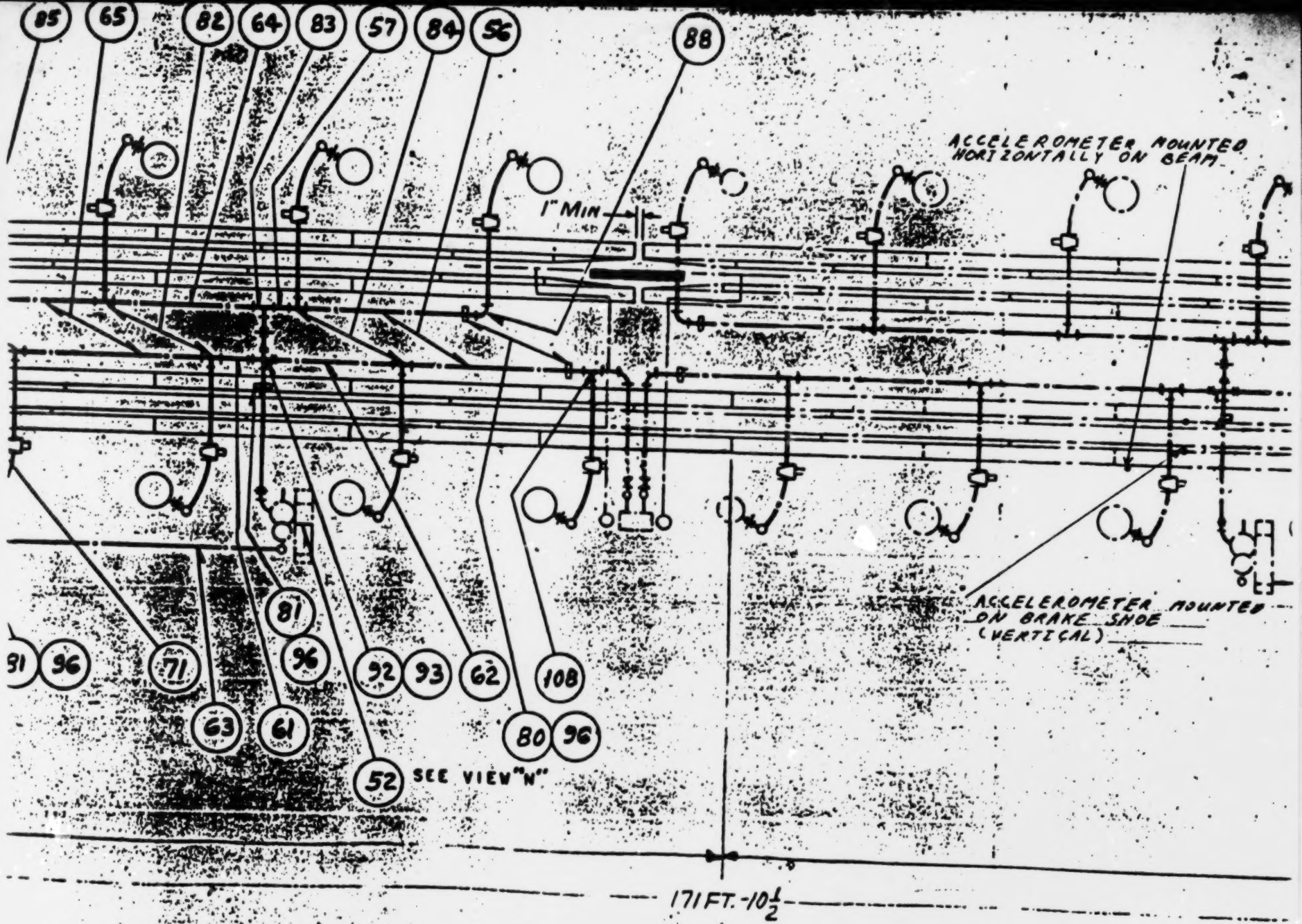


FIG 2
PLAN VIEW OF ACCELEROMETER LOCATIONS ON RETARDER
SCALE - 6" = 1'

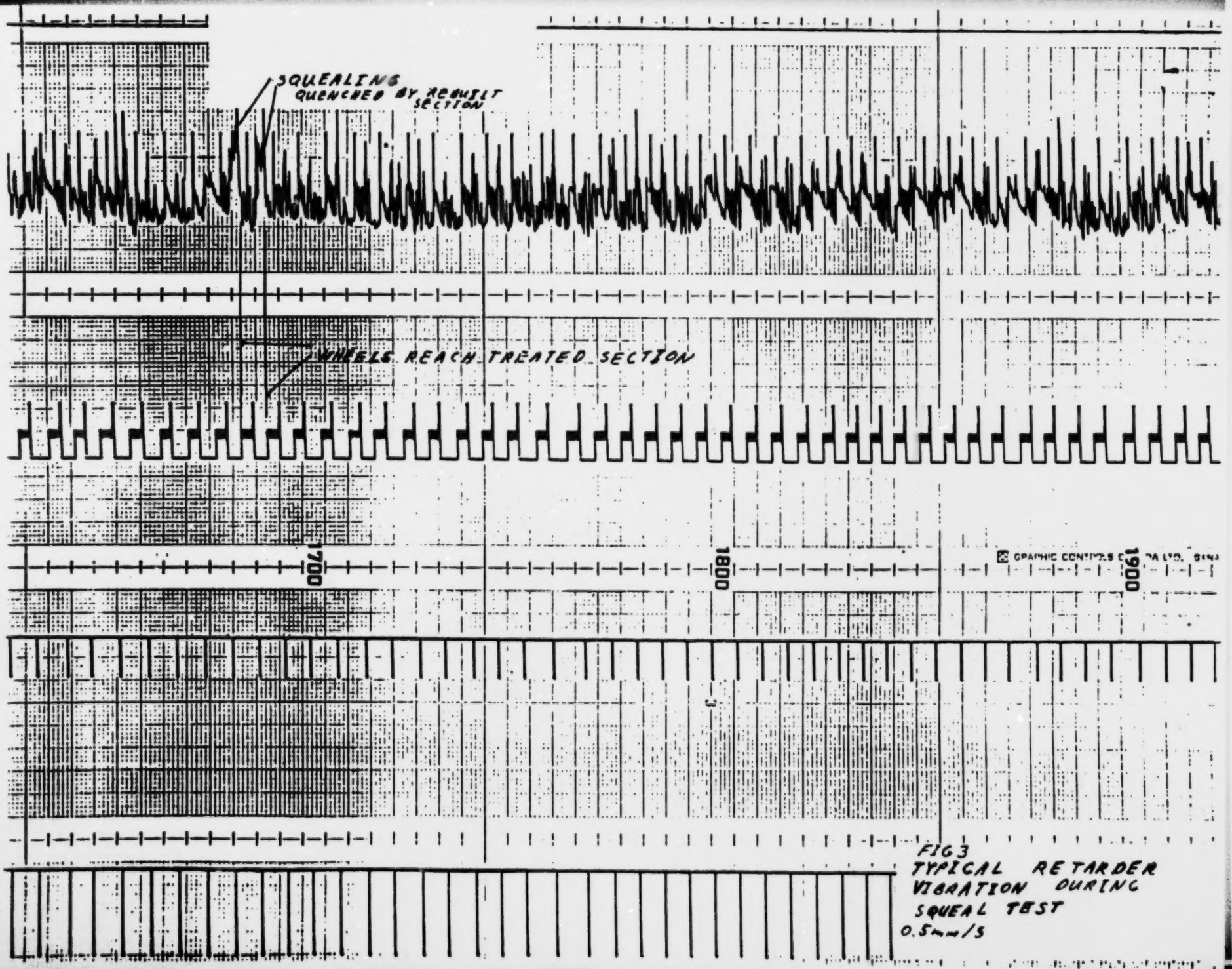


FIG 3
TYPICAL RETARDER VIBRATION DURING SQUEAL TEST
0.5mm/s

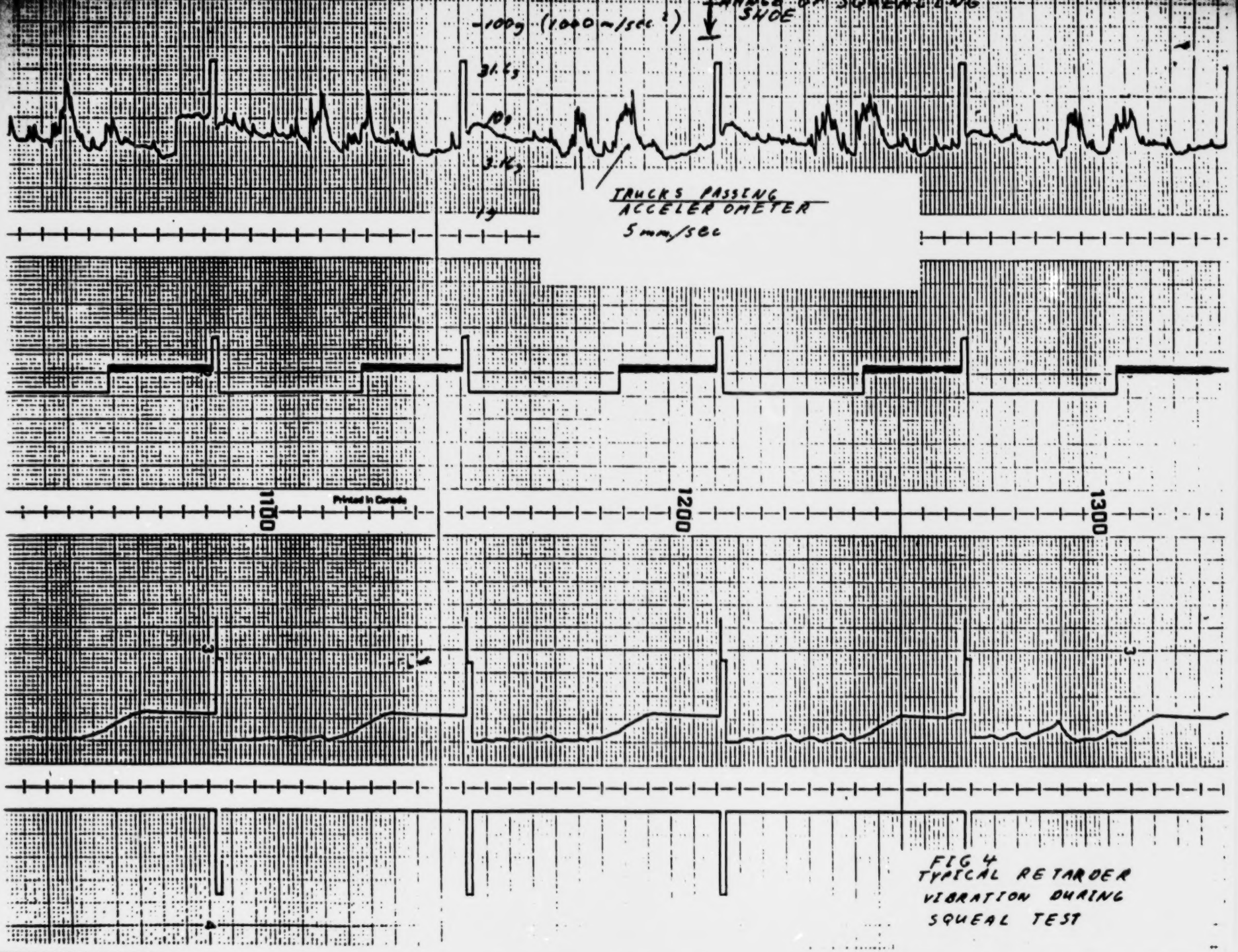


FIG 4
TYPICAL RETARDER
VIBRATION DURING
SQUEAL TEST

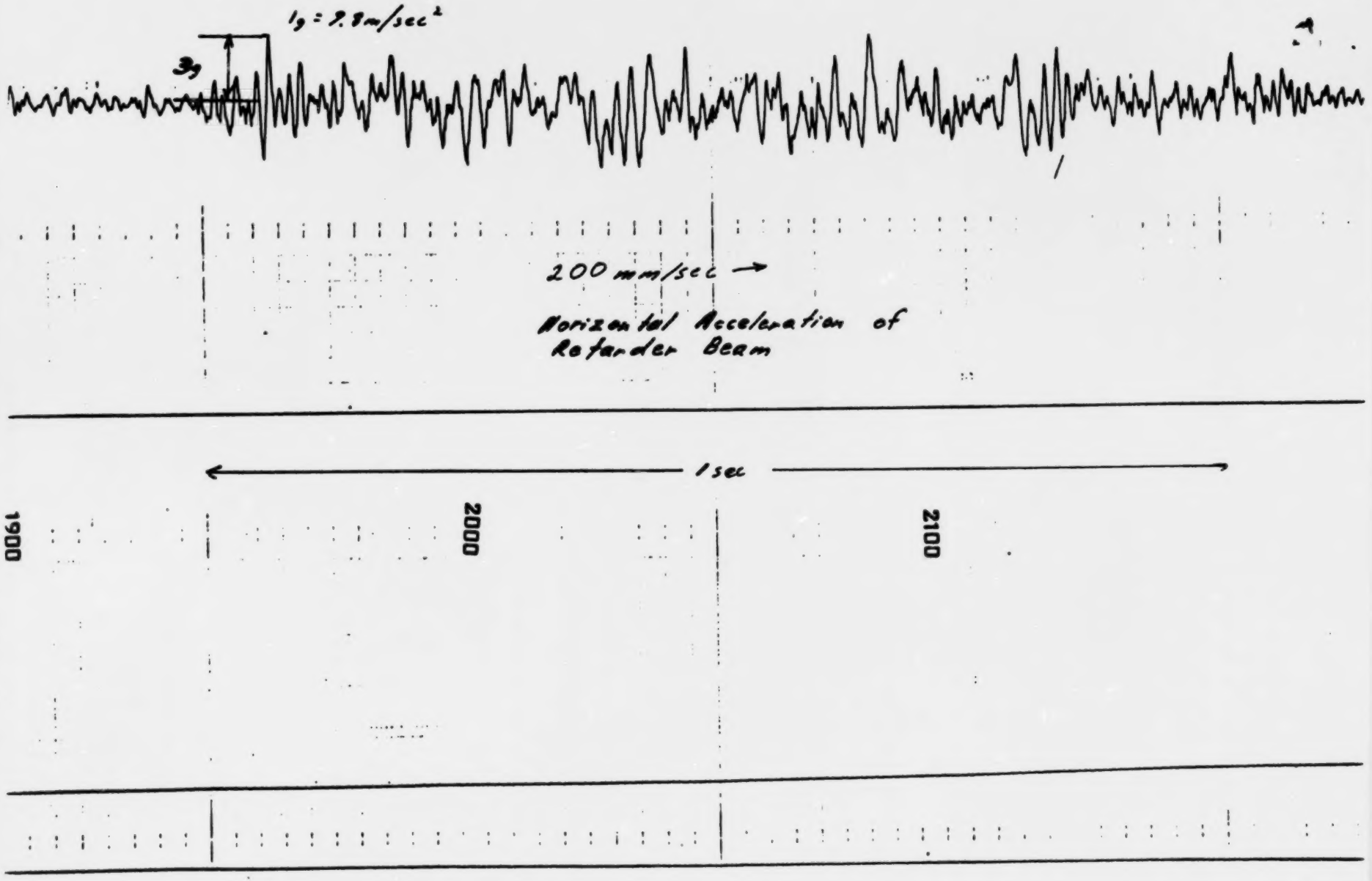
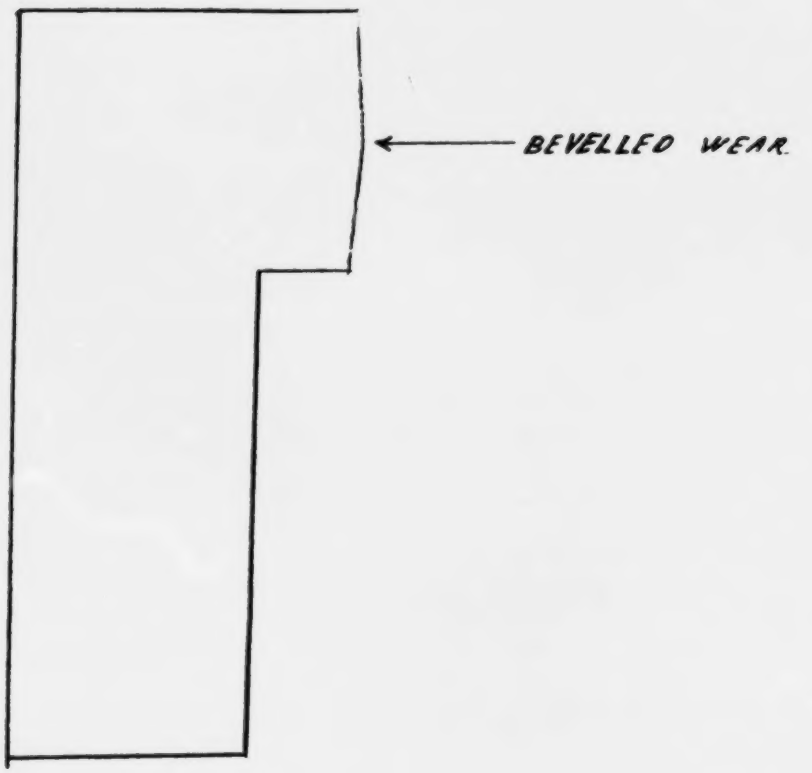


FIG 5
HORIZONTAL BEAM
ACCELERATION



SECTION OF SHOE

BARMAN
COULTER
SWALLOW
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Telephone (416) 245-7501

ENG	DRW	CHK

TITLE FIG. 6 RETARDER WEAR
PROJECT CP - REBUILT SHOE
CLIENT CP RAIL
DATE Feb 13 85
DWG #

APPENDIX B

J.E. Coulter - Report 2 - May 1, 1985

BARMAN
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John C. Swallow M.A.Sc., P.Eng.

May 01, 1985

CP Rail
Room 0-108,
Union Station, Toronto,
M5J 1E8

Attention: Mr. Gary Walker, Manager

RE: Retarder Rewelding Experiments Fluxofil
Continuous Weld

Gentlemen:

At your request we have reviewed the vibration monitoring data taken on the rewelded shoes which were rebuilt using Fluxofil material. The vibration transducer was mounted on the outside shoe approximately 15 feet from the lower track circuit trip point. There are a total of 8 rebuilt shoes mounted opposite each other on the south track of the master retarder. The accelerometer is mounted at the bottom end of the third shoe on the outside (southern most) row of the retarder.

In order to obtain a statistically valid sample, we reviewed approximately 1000 cars passing through the master retarder and selected for analysis only those events in which the front truck south side wheels were known to be squealing and could be identified as such on the charts. The weather during the test period was very summerlike and therefore quite representative of the time period when the residential neighbours most note the sound from the retarders. Of the 135 events, there were 48 in which we could confirm that the squeal was squelched or stopped in the test section. Another 56 events showed a substantial change in the squeal in the test section though we could not confirm that the squeal had stopped altogether. For 21 events we were reasonably sure that the wheels squealed right through the test section and for 10 events we could not determine whether they squealed right through the section or whether they had indeed been effected by this section. Summarizing, of the 135 events, 104 could be confirmed to have had a major effect on the squealing, 21 appeared not to have changed substantially and 10 could not be assigned to either group.

Cost
85/5

INTERPRETATION

Considering how marginal the onset of squeal is, we would interpret the group in which the squeal was changed in the test section as being unlikely to have started squealing had the entire retarder been treated. Obviously the event in which the squeal was squelched would also never have started to squeal in a fully treated retarder. The group in which we could not identify whether they were modified or squealed right through and the squealers are a little more difficult to assign, but if we assume that most of them would have squealed, then our overall reduction in the number of squealers is about 5 to 1.

It should be kept in mind that the current retarder system includes ductile iron shoes which are known from testing in the fall of 1984 to be reducing the number of squealers to about half the usual amount. Therefore, relative to the situation in which our study was initiated in July of 1984, when standard shoes were in use, we would project that a retarder equipt with the rewelded shoes would only squeal about 10% as often. We can put an error of estimate on this evaluation and say that the change can be anticipated to be reduced to between 7 and 15% of the original number of squealers as of July 1984. In terms of sound levels this would translate to a reduction between 7 and 13 dB. Translating into the perception of the population, the sound would be about 1/2 as loud as it was last summer.

NOTES

In addition to our previous findings in the studies based on the summertime period, we have now observed the pattern of squealing and the charateristics of the wheels etc. through the entire range of weather conditions under which the system must operate. We are now reasonably certain that the major factor in the amount of squealing is in the amount of contamination of the surfaces. Unlike the clean,dry surfaces in the summer, through the winter, the retarders were often coated in a greasy mixture of dirt, iron oxides ,possibly carbon, and iron filings from the retarders themselves. The main reason the heavier cars squeal more often than the light ones appears to be the high pressure at the contact surface which cleans the wheels in the upper portion of the retarder so that the surfaces rubbing in the lower portion of the retarder are free of contaminants.

Unfortunately, it is not possible to take advantage of the lower squeal in the dirty conditions since, when things get too dirty, it becomes to difficult to control the speed of the cars.

The projections we are making regarding the amount of squealing that will remain are in line with our original "best guess" of what might be achieved with the metallurgical changes. Yet to be determined is the long term wear rate (being analysed by the Yard Signals Staff) and the possibility of better materials being reviewed by Dr. Schey.

We trust the above will assist you in evaluating results of this experiment. Please do not hesitate to contact the undersigned should there be any questions.

Yours truly,
BARMAN COULTER SWALLOW ASSOCIATES

J. E. Coulter

John E. Coulter, B.A.Sc., P.Eng.
JEC/ss

APPENDIX C

Dr. J.A. Schey - Report 1 - March 19, 1985

University of Waterloo

1

Waterloo, Ontario, Canada
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Faculty of Engineering
Department of Mechanical Engineering
519/885-1211

Telex Number
069-55259

FINAL REPORT

WRI Project No. 412-02

FOR CP RAIL

This project was initiated to establish whether the twist-compression test as developed at the University of Waterloo can serve as a test method for evaluating candidate materials for the resurfacing of retarders.

Background

In the Agincourt Marshalling Yard of CP Rail, the retarders utilized to slow down railroad cars emit a high-level squealing noise (equivalent to about 1 hp radiating power) and also wear subtantially. The breaking effect is attributed to dry rubbing between the retarders and wheel flange. Barman Coulter Swallow Associates identified a stick-slip mechanism between wheel flange and retarder as the origin of the noise. The severe wear of the retarders indicates that dry sliding must occur much of the time. Wear debris accumulating under the retarders has a black appearance and greasy feel, although no analysis has been made to establish if it is essentially iron powder or whether it indeed contains significant amounts of oily material. Similarly, it is not known whether the wheel flanges also wear as a result of the flange-retarder contact. However, any one part of any one wheel is in engagement with the retarder only for a short time and the cumulative contact time is a very small fraction of the contact time the retarder rails experience.

Apart from noise and wear, the retarders do their job, except when larger quantities of oily substance are smeared on them, for example, when cars carrying turning chips soaked with cutting fluid pass through. The efficiency of the retarders is marginal for heavily loaded cars. Thus, indications are that the retarders are essentially operating under dry or very poorly lubricated conditions and that the high friction thus generated is essential for successful operation.

The broader aim of the present investigation is to determine whether worn retarders (or even new retarders) could be built up with a welded surface that would eliminate squealing; ideally, such a surface

GdW 85/3/27 Copies given to KS Young, JS Coulter, IC Cameron. 85/3/29.

would also wear less and, even though the cost of surfacing would be higher, the overall operating cost would be either less or not greater than at present. If the overall operating cost would turn out to be higher, the alternative of constructing a noise barrier would have to be considered.

Simulation Test

Laboratory simulation of tribological phenomena is notoriously difficult. The ultimate test is always the actual field application; however, the exploration of variables affecting friction and wear in full-scale tests is usually either impractical or too expensive or both. The ostensibly simplest solution is a test involving a scaled-down version of the actual contact situation. There is, however, the likelihood that scaling down will affect the localized pressure distribution, relative velocities, and heat balance. Therefore, building a test rig that incorporates the wheel-retarder geometry would not only be expensive but also uncertain in its validity. The alternative is to use a simulation test which does not necessarily resemble the physical layout of the actual contact but represents at least some of the fundamental features typical of the contact. For successful simulation, an understanding of these fundamental features is needed.

The background to the problem was discussed at three meetings at the University of Waterloo between the writer and Mr. John Swallow (Nov. 5, 1984), Messrs. Swallow and Gary Walker, CP Rail (Nov.28, 1984), and Messrs Swallow, Walker, Ken S. Young, CP Rail, and Lee C. Groves, Crothers (March 14, 1985).

Barman Coulter Swallow Associates have analyzed the situation and suggested that contact pressures range between 1300 and 13 000 psi, sliding velocities are on the order of 100 in/sec, and that a stick-slip mechanismn between the unlubricated surfaces is the culprit in noise generation. They felt that a test that could induce squealing or, failing that, evaluate sticking and sliding friction, would be useful.

From the description of the problem we judged that adhesion between wheel and retarder must be responsible for high friction and the formation of cold-welded joints. Shearing and tearing of such joints can lead to violent variations in friction force, similar to a stick-slip mechanism, and can also result in rapid adhesive wear. Thus, adhesive friction and wear mechanisms appeared consistent with all observations. On this basis, we recommended the twist-compression test that has been successfully used to investigate adhesion, adhesive wear, and all situations involving unlubricated or lubricated sliding under severe contact conditions.

In the twist-compression test, one specimen is made into a flat anvil which is pressed against the end face of a hollow, rotating cylindrical specimen (Fig. 1). Interface pressure is adjusted by setting the pressure on a hydraulic cylinder; variable speed rotation is imposed by a hydraulic motor; and the resulting torque is measured by the deflection of a beam. Recordings of torque are made as a function of time, and a coefficient of friction is calculated from the frictional force F (= torque/moment arm) divided by the normal force. In addition to the magnitude of the coefficient of friction, variations of torque from revolution to revolution and within one revolution give important clues regarding contact conditions. Furthermore, both anvil and specimen are inspected for evidence of cold welding, wear, surface damage, and metal transfer.

In recommending the test we recognized that we can simulate only the fundamental aspects of the real situation. The masses of the two specimens are much smaller than that of either the wheel or retarder; contact is continuous and prolonged, rather than discontinuous; heat-build up is rapid and, at higher speeds of rotation, leads to friction welding between specimen and anvil; the stiffness of the system is quite different from the field conditions and vibrations, if set up at all, may occur at entirely different pressures or sliding speeds. Nevertheless, the essential feature--namely the sliding of unlubricated surfaces under pressure--is retained, and a situation suitable for evaluating adhesion and adhesive wear between the contacting materials is set up.

Experimental Program

On the basis of the above considerations, we proposed a two-phase investigation (see our letter proposal of Nov.30, 1984).

The first phase was to involve a parametric study to establish whether vibration and noise generation can be induced under laboratory conditions and, if not, whether test conditions can be found that are relevant to the problem. Rotating specimens were to be cut from an actual wheel, and anvils from a retarder. The enclosed drawings of Barman Coulter Swallow (Fig.2 and 3) show that the orientations of specimen and anvil were chosen to represent the same rubbing faces as are in contact in the actual situation.

A successful conclusion of the first phase was to be followed up by a second phase in which various hard-surfacing materials would be recommended for building up anvils by welding and, on the basis of test results, the best of these materials were to be used in field tests.

Parallel with this work CP Rail was to conduct field tests, using a technique empirically developed in Texas. The technique involves welding

isolated patches, of approximately 4-in length and 1.5-in width, separated by 0.5-in gaps, along the worn retarder surface. Surfacing is done with Xuper 6868-XHD and Xuper NucleoTec 7222-XHD welding sticks alternating from patch to patch. The application technique was originally developed with the purpose of increasing retarder life, and a 100% increase in life was reportedly obtained. As a side effect, it was observed that these built-up retarder sets generated no noise.

Experimental Program, Results, and Discussion

On Jan.4, 1985, CP Rail approved the first, fixed-cost phase of the program.

Wheel vs. Retarder

On Jan. 23, 1985 the first specimens were received and, after grinding the anvils to the 24 to 36 in AA surface roughness required for the test, were tested on Jan. 25. Hardness tests showed that the wheel had a hardness of HRB 98, and the retarder HRC 30, corresponding to a 85 kspi and 140 kpsi tensile strength, respectively. From our experience, these values are low for materials destined for severe sliding contact. Therefore, on the basis of past experience, we set the sliding speed very low, at 6 rpm (approx. 20 in/min).

Interface pressure was first set at 10 000 psi; immediate cold welding of the specimens occurred, with the anvils becoming severely gouged and rotation changing to an orbital motion around the point of most severe interference. A test at 3000 psi gave the same result. The lowest pressure that can be generated on the twist-compression tester is 1000 psi; even here, welding set in soon and the coefficient of friction rose rapidly from 0.4 (a value typical of essentially dry sliding) to 2.4 (representing gouging of the specimens by the gross welded junctions that have been formed, Fig.4). Only this result is entered in the attached Table 1.

The test results confirmed that adhesion between rail and retarder is high. Metallographic examination showed that the wheel was a steel of roughly eutectoid (0.8% C) composition with a fully pearlitic structure, whereas the retarder had a spheroidal structure. It is well known that dry sliding between similar ferrous materials inevitably results in high adhesion, and the high wear rate experienced in the field is only to be expected under these conditions. No squealing could be induced since welding occurred even before vibration could set in (assuming that vibration would develop in this test at all). However, the results clearly indicated that adhesion must be the major culprit and must be responsible for noise generation, essentially through a mechanism of repeated welding and shearing. On the basis of this conclusion we explored some other materials that were available in our laboratory.

Alternate Materials

We knew from prior work--including a recently concluded doctoral research--that adhesion in unlubricated contact can be reduced by two main actions: increasing the hardness of one of the contacting materials, and changing the composition to create a material pair between which there is inherently low adhesion.

The effect of hardness could be tested by running the specimen made of the wheel material against oil-hardening steel anvils quenched and tempered to HRC 56 (corresponding to approx. 315 kpsi tensile strength). At 1000 psi, the coefficient of friction was around 0.5, typical of dry sliding, but pickup was very light, with the surface burnished rather than damaged (Fig.5), and no vibration could be detected in the recorded trace. On increasing the pressure to 3000 psi, the frictional coefficient remained at 0.5, some pickup classified as "light" was observed (Fig.6), and slight vibration was visible in the recorded trace from the fourth revolution on. At 9000 psi, the coefficient of friction was unchanged but pickup became heavy (Fig.7), and vibration was clearly evident from the 5th revolution on. An audible noise was also emitted. The same observations were made at 10 000 psi pressure (Table 1).

We knew that compositional effects become significant when the mating partner is an inherently low-adhesion material such as a cobalt-base alloy. We had, from a previous investigation, a plate of Haynes 25, a cobalt-base superalloy of nominal 10 Ni, 20 Cr, 15 W, 0.1 C composition. This material was developed for high-temperature service and is characterized by high hot strength and ductility but relatively low room-temperature hardness (HRB 96, corresponding to roughly 105 kpsi tensile strength). Thus, it would not be expected to give very low wear but it should show low adhesion. This was indeed the case when anvils were made out of this material. The surface became burnished, and there was only very minor metal transfer (Fig.8). The coefficient of friction was low, 0.37 - 0.4, and very steady. It did not increase during the six revolutions taken as the standard test duration, and there was no evidence of vibration in the recorded trace.

Welded Anvils

Meanwhile, CP Rail proceeded with the test of the surfaced retarders and we received anvils built up with 2222-XHD and 6868-XHD. After grinding to the required surface finish, the hardness of the surfaces was found to be HRB 86 (corresponding to 80 kpsi tensile strength). The coating 2222 gave very rapid surface damage (Fig.9), almost like the untreated retarder. Coating 6868, even though of only

the same hardness, allowed continued rotation; surface damage was medium. Indeed, a third specimen tested on March. 14, 1985 survived very well, with only light damage, indicating that deposition techniques or random variables may affect the results. Clearly, the overall situation was greatly improved against the untreated retarder.

Interpretation of these results is not easy since relevant information on the compositions of the deposits is missing. The environmental statement shows only that 6868 contains a higher proportion of alloying elements such as Cr, Ni, and Ti. Judging from the hardness and test behavior, 2222 appears to be a typical filler electrode, whereas 6868 must have a composition that allows it to resist adhesion reasonably well. This may explain the observed performance of the built-up retarders: they wore quite heavily but did not emit noise, and the wear pattern suggests that 6868 is better able to resist the prevailing contact conditions.

At this point the aims of Phase 1 were accomplished, however, there was still time available and we branched out into what originally was considered the second phase.

Experimental Materials

On the basis of observations, we recommended that a number of welded surfaces should be prepared for testing. In choosing the materials, we were limited to those that were available at Crothers as welding wires or welding sticks. We chose those that had either a higher hardness or a somewhat different composition. The following materials were tested (Table 1):

1 Stoody's 105. This is a 0.16 C, 2.7 Mn, 0.8 Si, 3.4 Cr, 1.0 Mo, 0.4 V electrode with an as-deposited hardness of HRC 45 (the specimen tested in our lab had a hardness of HRC 44). Somewhat surprisingly, this suffered severe damage in testing and the coefficient of friction was also quite high and inconsistent.

2 Fertamatic 922 is an electrode of a composition corresponding to AISI 4130 and is heat treatable by hardening. We subjected the specimen to the standard heat treatment for 4130 and found that the backing (retarder material) became fully martensitic with HRC 60, whereas the weld layer had a hardness of only HRC 29. Results were very poor, with almost immediate welding.

3 Fluxofil 58 is a steel of 0.45 C, 1.6 Mn, 0.7 Si, 6 Cr, 0.7 Mo composition, with an as-deposited hardness of HRC 57 - 62. This coating gave the results expected from its hardness, with a steady or only very slightly rising coefficient of friction and only moderate surface damage.

It should be noted that on 03.14 the results were somewhat affected by fluctuations in hydraulic pressure because, from the same hydraulic oil supply, some fatigue rigs were also driven. Other experiments were done after hours when the fatigue rigs were off.

From the recordings, the following additional observations can be made regarding the steadiness of the torque trace (Fig.10):

(a) The most steady torque is given by Haynes 25.

(b) The torque trace of heat-treated steel (HRC 56) shows periodic variations caused by the slight misalignment typical of most specimens and anvils; it is essentially steady throughout the six revolutions.

(c) Fluxofil 58 gives a similar trace but torque rises slightly; it could possibly rise suddenly at a later time once surface damage accummulates. (Such a rising trace, with a steeper slope, was also observed with steel at 3000 psi and, particularly, at 9000 and 10 000 psi.)

(d) 6868 gave a trace similar to (c) on 03.14 but a more irregular, randomly fluctuating trace on previous occasions.

(e) Wild fluctuations were typical of Stoody's 105 and 2222, and torque increased greatly during the sixth revolution with 2222, indicating severe surface damage.

(f) Immediate welding caused a rapid rise of torque with Vertamatic 922 and also with the original retarder material, indicating that all unlubricated sliding results in junction formation.

These experiments confirmed that the basic diagnosis was correct. The number of experiments was less than envisaged, but they led further into the second phase. We were able to show that adhesion and surface damage can be reduced by increasing the hardness of the retarder surface, but significant effects are obtained only if this hardness is HRC 58 or over; improvements are also obtained when a low-adhesion coating is used.

Future Work

The results have been discussed with Messrs. Walker, Swallow, Young, and Groves. They found the laboratory observations consistent with field observations. The debris generated during the test is similar to that observed at the base of the retarders. A fish-scale like pattern observed on the retarders is similar to one developed in the twist-compression test.

In one of the tests (Stoody's 105, dated 02.28) the anvil was, by accident, first tested with the residue of the grinding fluid, and the coefficient of friction was low and no metal transfer was observed. In contrast, immediate pickup occurred after degreasing. This pickup was observed also in the repeat test on 03.14. This indicates that even small amounts of a lubricant can significantly change the friction and wear behavior. Observations of retarder surfaces suggest that some oil may be present much of the time, and this would significantly reduce the rate of wear and metal transfer. This may explain why, even with the unfavorable, similar material combination, the life of retarders is still measured in months or even a year, with a total of perhaps 1.5-in worn away. It remains to be decided whether any experiments should be performed with slightly lubricated surfaces.

Returning to the unlubricated tests, the next step in a future second phase should establish a base line, using the best available anti-adhesion material. This would indicate building up anvils with one of the Tribaloys. They combine high hardness with compositions that are expected to give minimum adhesion; this is especially true of the cobalt-based Tribaloy T-800:

Tribaloy T-800: Co - 28 Mo - 17 Cr - 3 Si; HRC 54-64

Tribaloy T-700: Ni - 32 Mo - 15 Cr - 3 Si; HRC 45

If Tribaloy T-800 does indeed give the expected absence of surface damage, then some retarders should be built up and tested for absence of squealing. Very low wear can be expected, so that an economic assessment should be promising.

In view of the tight time schedules, it would also be worth while to test retarders built up with Fluxofil 58 as the best member of the weld overlays tested hitherto.

Further twist compression experiments could be conducted with Stoody 102, Stoody 4552, Stoody 103 and McKay Tube-Alloy 258-S and 255-S. The data sheets provided by Lee Groves indicate that these overlays could be promising; they give as-deposited hardnesses of HRC 50 and over, and Tube-Alloy 255-S and Stoody 103 have a high enough chromium content (29%) to make a difference from the adhesion point of view. These experiments could prepare a fall-back position in case Tribaloy would prove to be uneconomical.

The cost of one test, including surface grinding, remachining of rotating specimen, hardness testing, evaluation, equipment use, and brief report (shorter than the present one) is $150.00.

Waterloo, 1985 March 19.

John A. Schey
Professor
Dept. Mech. Eng.

University of Waterloo

Waterloo, Ontario, Canada
N2L 3G1

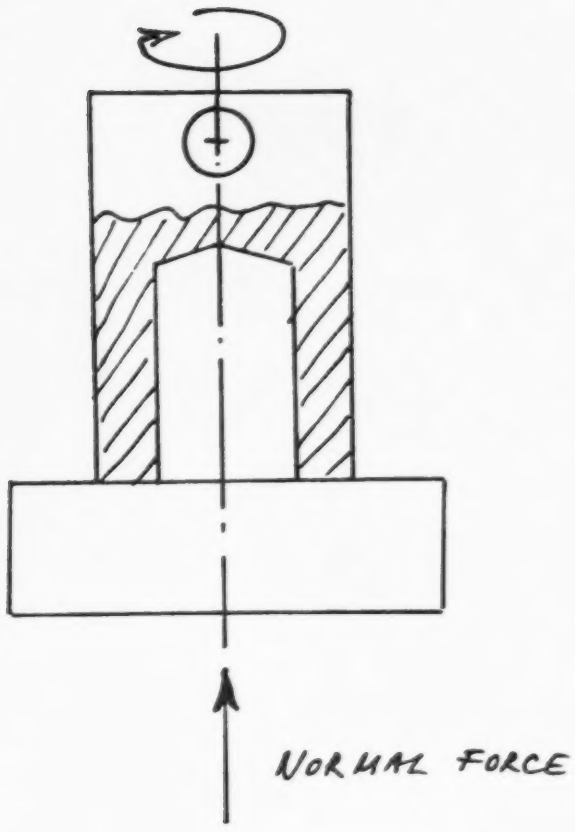
Faculty of Engineering
Department of Mechanical Engineering
519/885-1211

Telex Number
069-55259

TABLE 1

Results of Twist-Compression Experiments

Date	Anvil material	HRC	HRB	Pressure psi	Coefficient of friction	Pick-up	Vibration
01.25	Retarder	30		1000	0.4 - 2.4	welding	
02.07	Steel (No.10)	56		1000	0.55	v.light	No
03.14	(No.1)	56		1000	0.55	v.light	?
01.29	(No.12)	56		1000	0.4 - 0.5	v.light	No
01.29	(No.12)	56		3000	0.5	light	4th rev
01.29	(No.1)	56		9000	0.5	heavy	5th rev
01.25	(No.11)	56		10000	0.25 - 0.5	heavy	5th rev
01.25	Haynes 25		96	1000	0.37	v.light	No
02.07	Haynes 25		96	1000	0.4	v.light	No
03.14	Haynes 25		96	1000	0.35	v.light	?
02.07	2222 XHD		86	1000	0.25 - 1.2	v.heavy	?
02.07	2222 XHD		86	1000	0.8	v.heavy	?
03.14	2222 XHD		84	1000	0.5 - 1.5	v.heavy	?
02.07	6868		86	1000	0.5	heavy	3rd rev
02.07	6868		86	1000	0.5	heavy	3rd rev
03.14	6868		90	1000	0.45	light	?
02.28	Stoody's 105	44		1000	0.25 - 0.5 0.8 - 2	(oily) No (degreased) heavy	4th rev
03.14	Stoody's 105	41		1000	0.3 - 1	heavy	?
02.28	Vert.922	29		1000	0.5 - 2.5	(heat-treated) v.heavy	
03.14	Vert.922		97	1000	2.5	v.heavy	
03.14	Fluxofil 58	61		1000	0.4 - 0.5	light	?
03.14	Fluxofil 58	61		1000	0.4 - 0.55	light	?



SPECIMEN OD = 1.25 in
ID = 0.75 in
AREA = 0.78 in^2 = 503 mm^2

NORMAL FORCE:
CYLINDER AT 100 psi gives 3.5 kN

PRESSURE: AT 100 psi = 7 N/mm^2 = 1000 psi

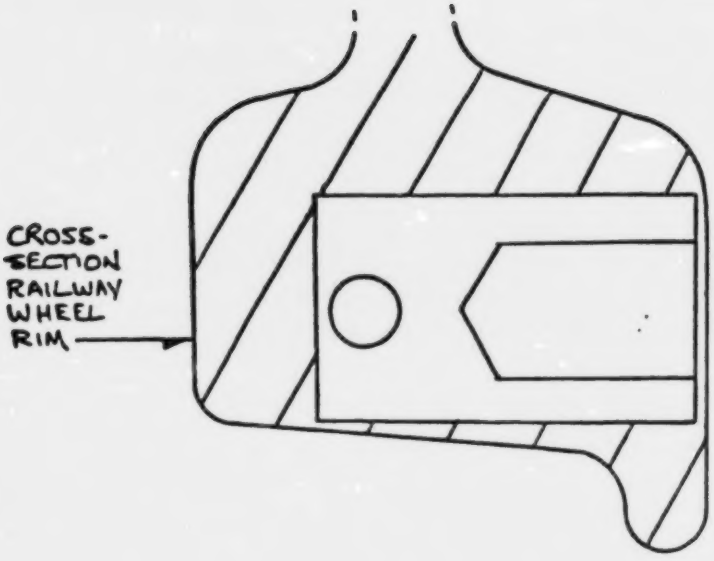
TORQUE: 0.1 V OUTPUT = 23.7 N.m on 13-mm arm

FRICTION FORCE = 23.7/0.013 = 1800 N at 0.1 V

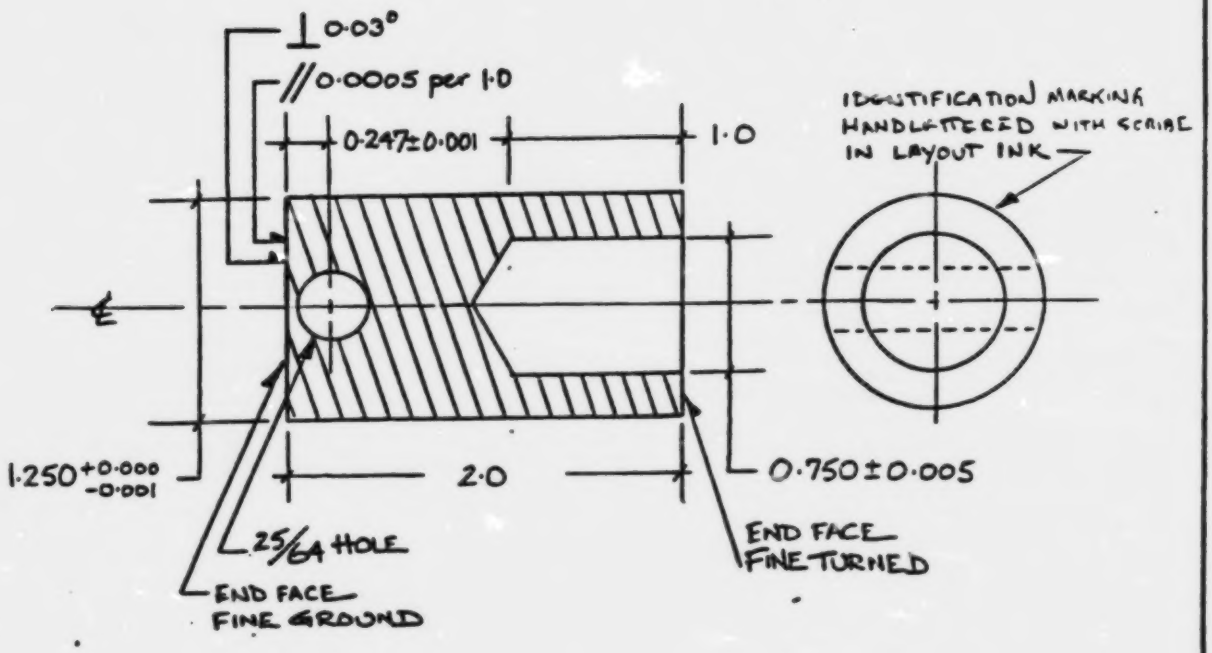
∴ AT 1000 psi, 0.1 V CORRESPONDS TO $\mu = \frac{1800}{3500} = 0.52$

FIG. 1 TWIST-COMPRESSION TEST

85.03.17



MATERIAL:
SAW CUT FROM WHEEL RIM AS SHOWN
NOTE: DO NOT FLAME CUT OR USE OTHER METHODS INVOLVING HEAT.



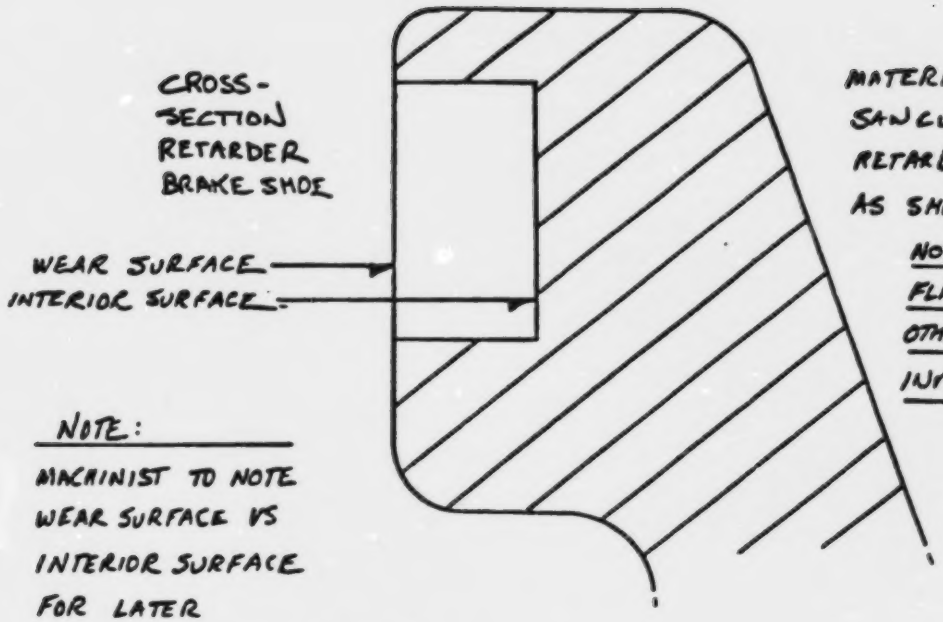
QUANTITY: 20

IDENTIFICATION MARKING:
CPR-W

ALL DIMENSIONS IN INCHES
TOLERANCE: ±0.010 EXCEPT WHERE NOTED

BARMAN COULTER SWALLOW ASSOCIATES	Suite 401, 1 Greenshaw Drive, Etobicoke, Ontario M9W 5C8 Telephone (416) 245-7501			TITLE SPECIMEN-TWIST COMPRESSION	
				PROJECT SQUEAL-LABORATORY TEST	
ENG JCS	DRW JCS	CHK		CLIENT CPR	
				DATE 84/12/11	DWG # 1 of 2

FIG 2

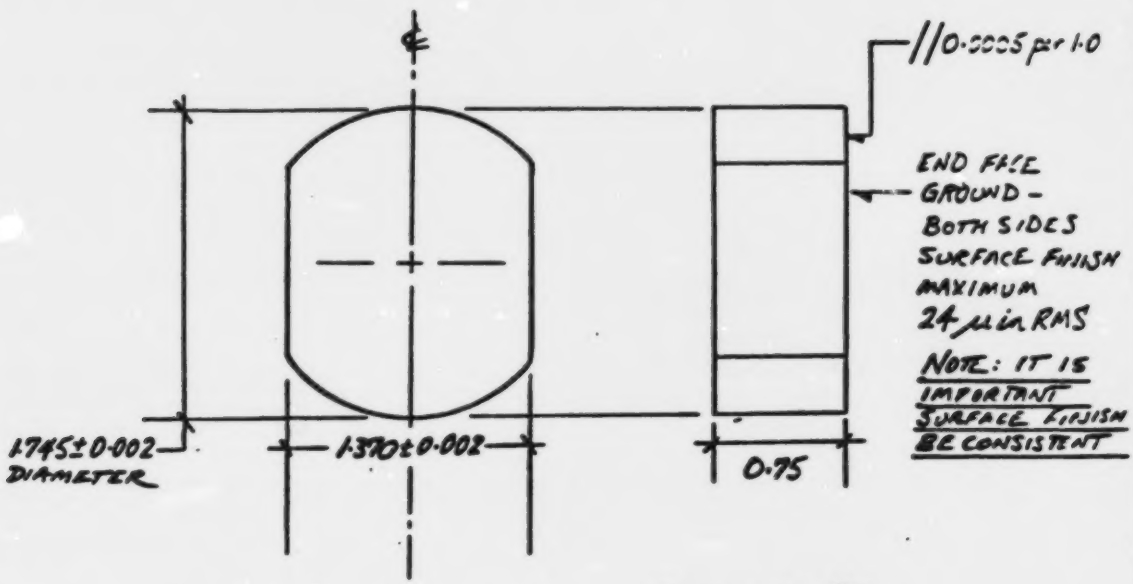


MATERIAL: SAW CUT FROM RETARDER BRAKE SHOE AS SHOWN

NOTE: DO NOT FLAME CUT OR USE OTHER METHODS INVOLVING HEAT

NOTE:

MACHINIST TO NOTE WEAR SURFACE VS INTERIOR SURFACE FOR LATER IDENTIFICATION MARKING



NOTE: IT IS IMPORTANT SURFACE FINISH BE CONSISTENT

QUANTITY: 20

IDENTIFICATION MARKING:

CPR-A

MARKING TO APPEAR ON OPPOSITE SIDE TO "WEAR SURFACE"

ALL DIMENSIONS IN INCHES
TOLERANCE:
±0.010 EXCEPT WHERE NOTED

BARMAN COULTER SWALLOW ASSOCIATES	Suite 401, 1 Greenbriar Drive, Rexdale, Ontario M9W 1C8 Telephone (416) 245-7501			TITLE	ANVIL - TWIST COMPRESSION
				PROJECT	SQUAL-LABORATORY TEST
	ENG	DRW	CHK	CLIENT	CPR
	JCS	JCS		DATE 84/12/11	DWG # 2 OF 8.

FIG. 3

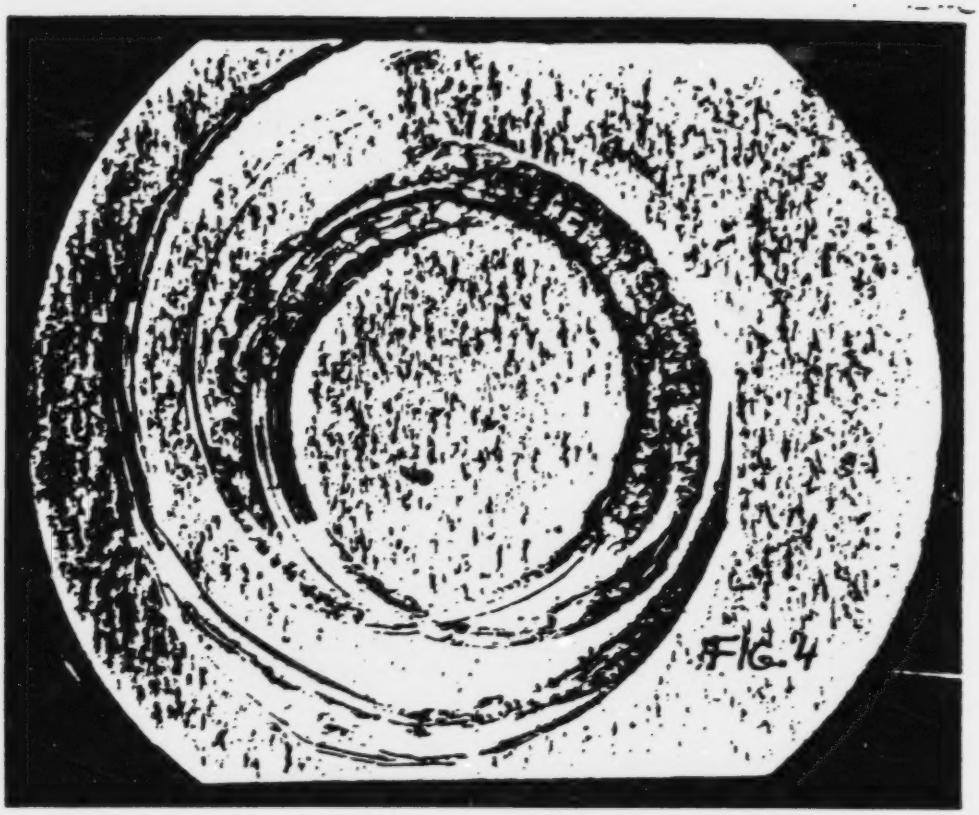


FIG. 4

RETARDER 1000 psi

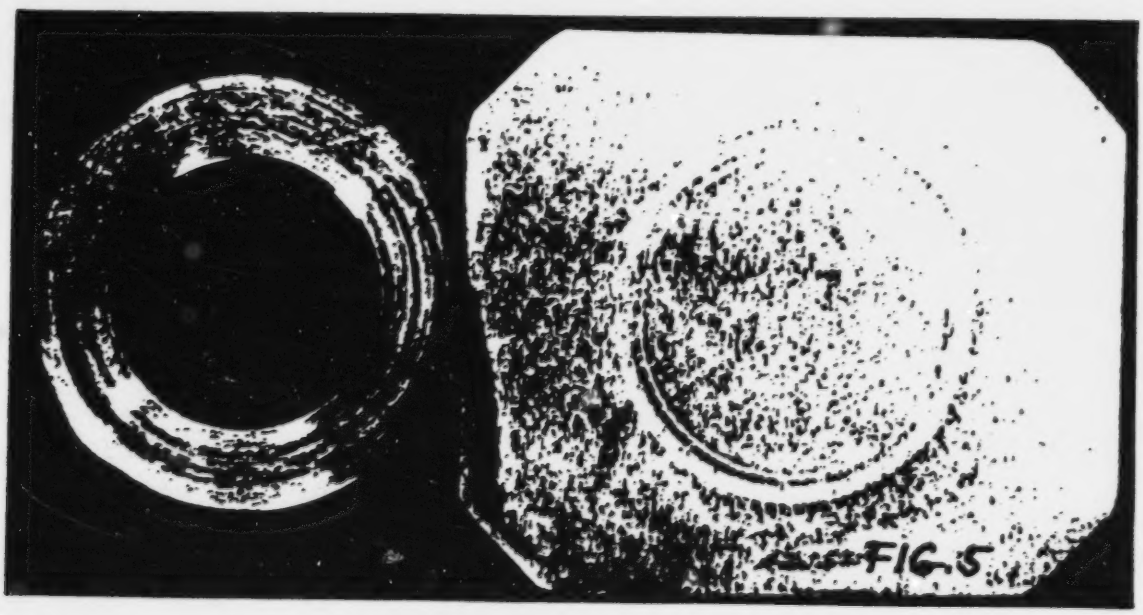


FIG. 5

STEEL HRL 56 1000 psi

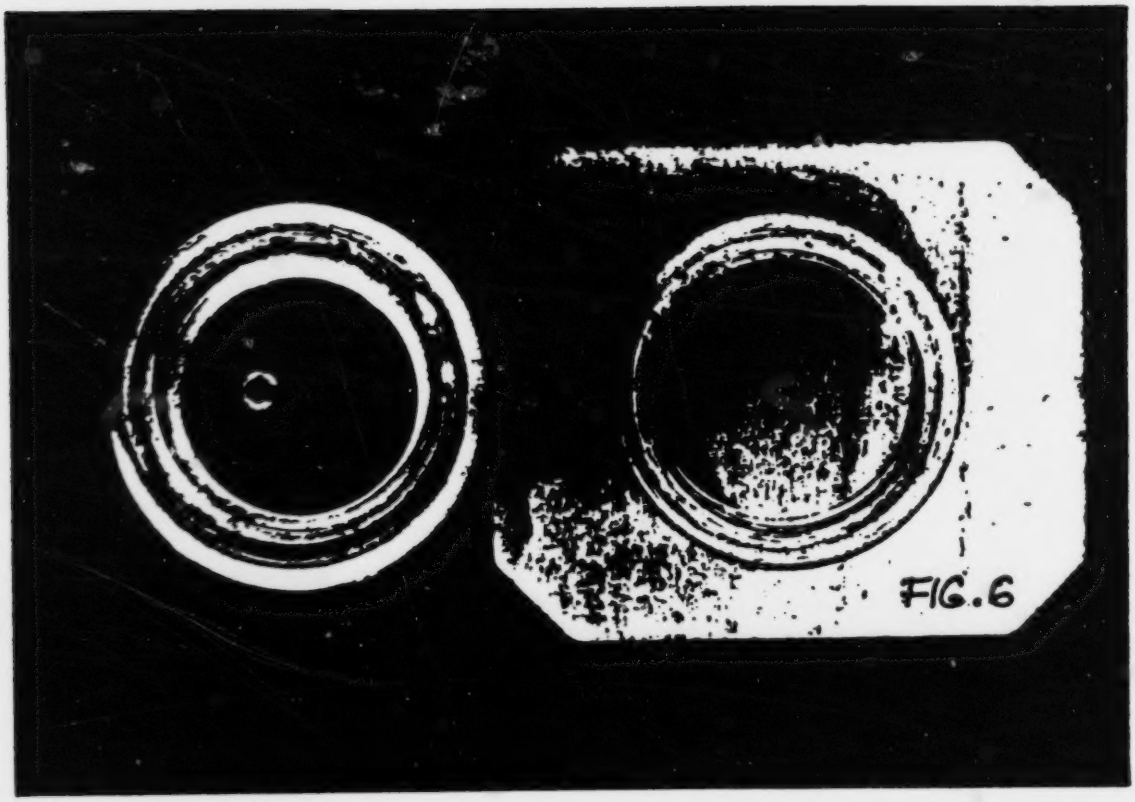


FIG.6

STEEL HRC 56 3000 Ni

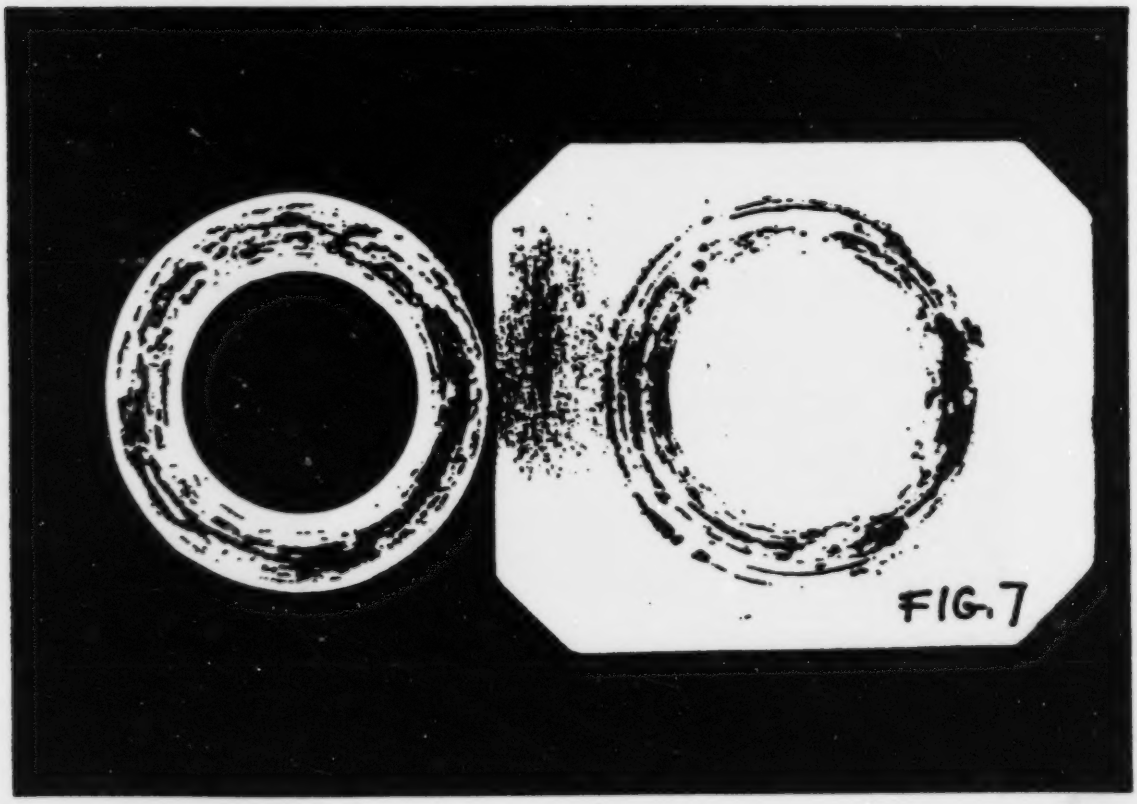
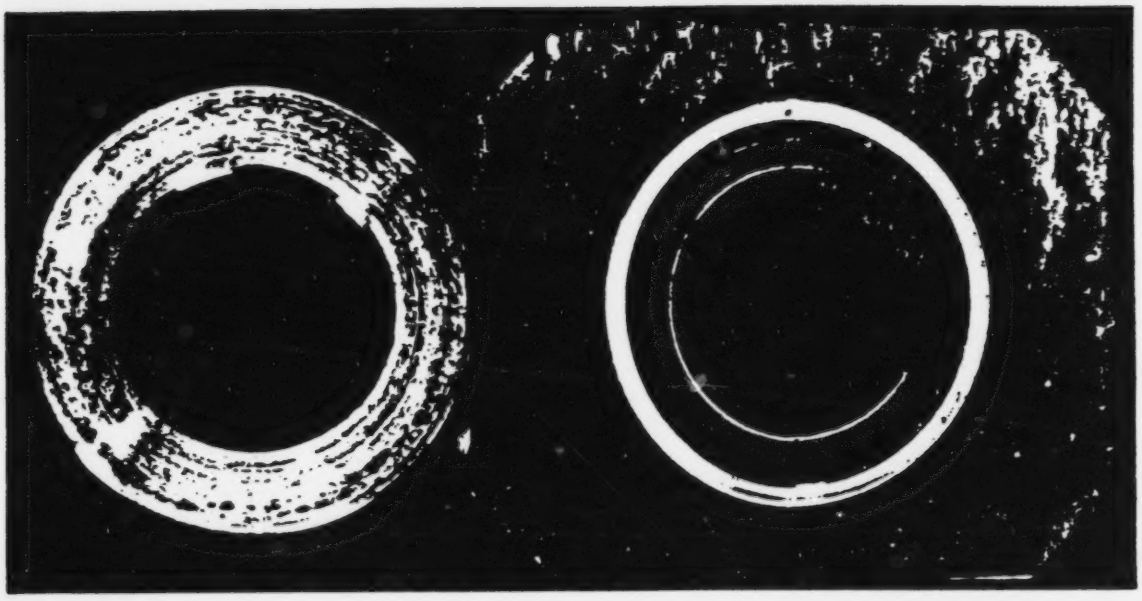
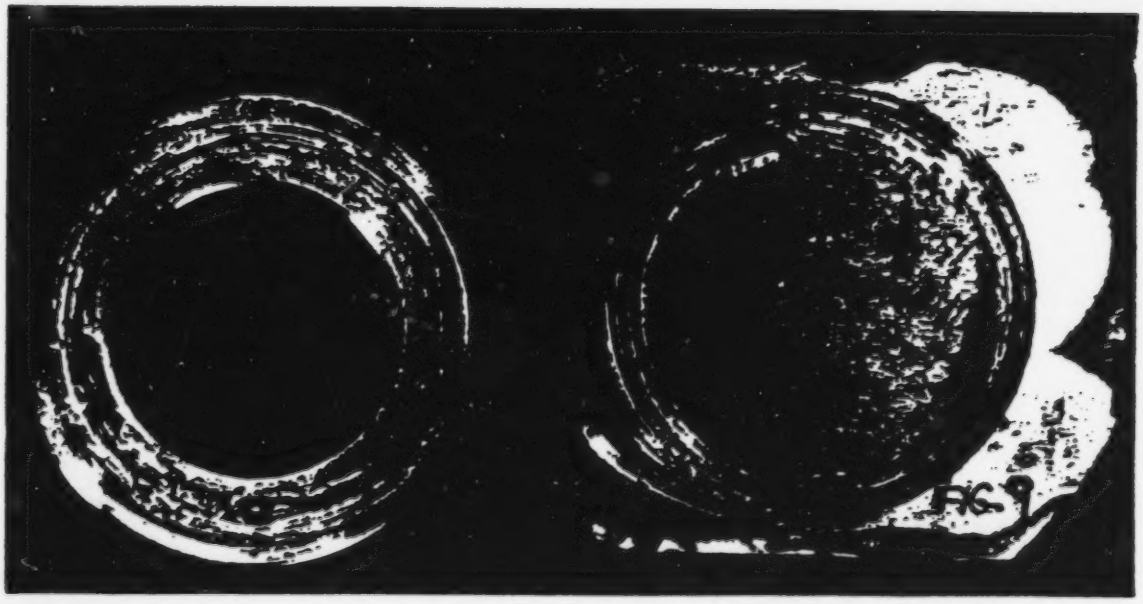


FIG.7

STEEL HRC 56 9000 psi



Haynes 25 1000 psi



2222 1000 psi

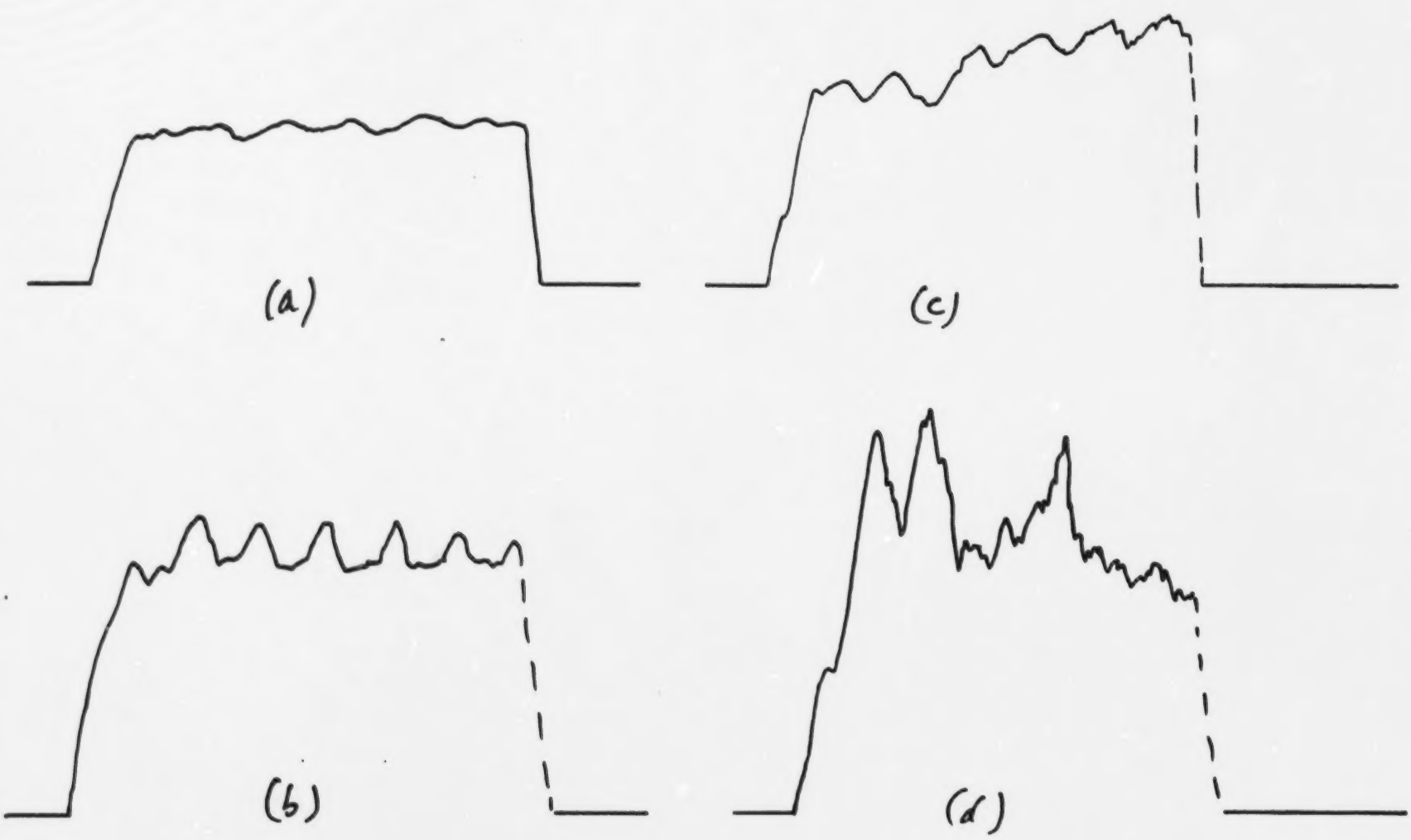
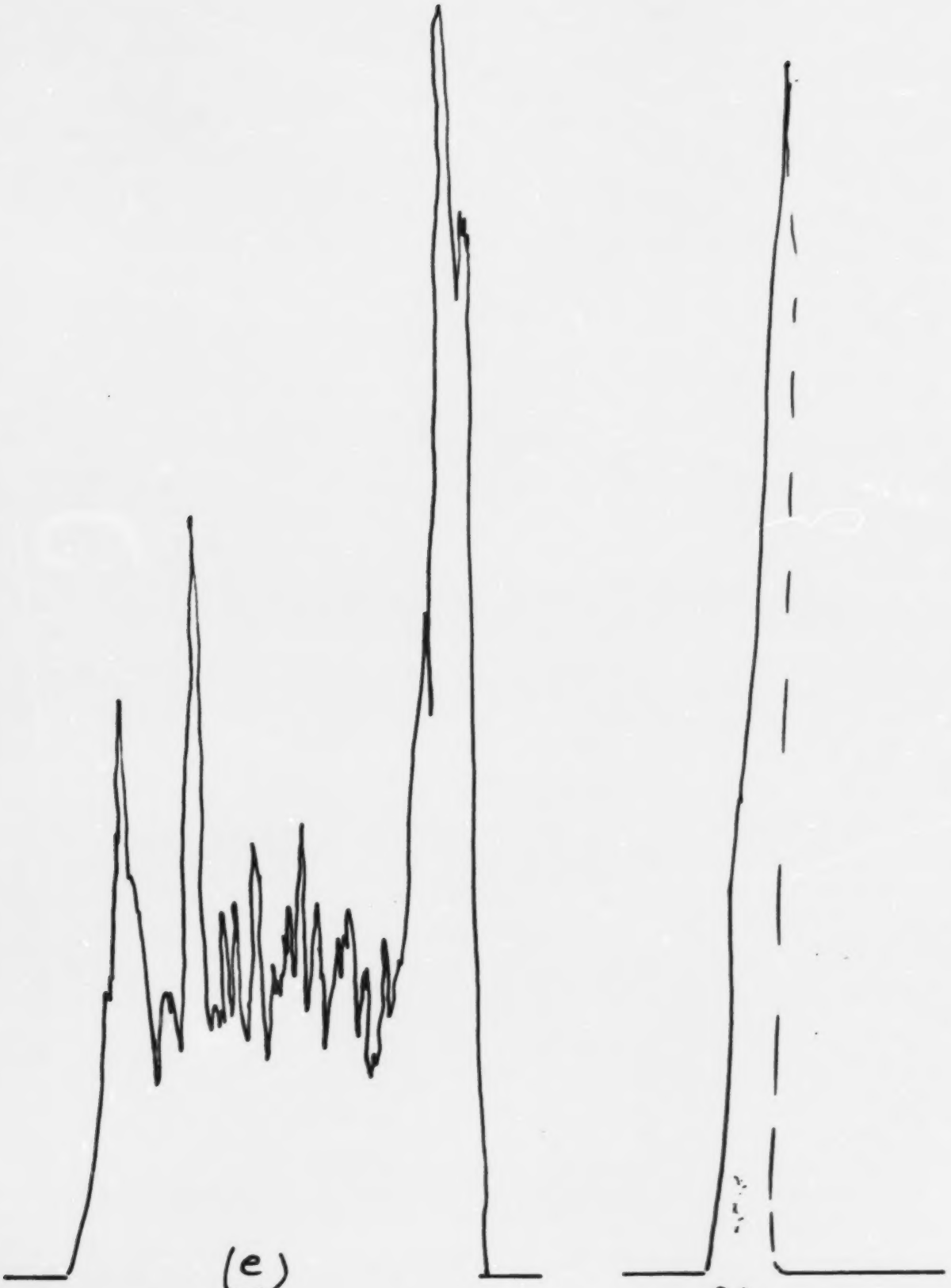


FIG. 10 TYPICAL TORQUE TRACES

05.02.17



(e)

(f)

IR in (contd.)

Appendix D

Dr. J.A. Schey - Report 2 - May 12, 1985.

University of Waterloo

Waterloo, Ontario, Canada
N2L 3G1

Faculty of Engineering
Department of Mechanical Engineering
519/885-1211

Telex Number
069-55259

May 12, 1985

Performance of Hardfacing Alloys

We tested the samples sent under cover of Lee Groves's letter.

As indicated on the phone, we had considerable difficulties with several of the specimens. Some were welded up into a slightly conical form, thus the requisite 1.25-in diameter contact area could be obtained only by removing a substantial thickness by milling. Others had a top surface that was far from parallel to the bottom surface of the specimen, therefore, they too had to be milled off. There is a possibility that on some parts of some specimens no hardfacing was left.

This seemed to be the case with one specimen coated with Stoody 4552, on which hardness dropped from HRC 53 on one half to HRC 33 on the other half of the test surface. There is also a puzzling variation with Stoody 102: one specimen was very hard (HRC 57-60) whereas the other was soft (HRB 79-88). Also, with Stoody 103, one specimen was hard (HRC 52-56) and the coating was cracked in one place: the other specimen was softer (HRC 32-40), with no trace of cracking, indicating that some differences due to welding techniques have crept in. Both specimens coated with Teledyne 255 S showed some porosity and cracking.

After finish grinding of the surfaces, the specimens were tested, and the results are shown in Table 1. We discuss here the coatings in order of decreasing performance:

Undoubtedly, Marfac 6 is the best material in terms of resistance to metal transfer. It is described as a cast cobalt-chromium-tungsten alloy. Its hardness is not very high, therefore, its good performance must be attributed to low intrinsic adhesion which in turn must be due to the high cobalt and chromium content.

The next best material is Teledyne 255 S. Its relatively high hardness and the high (29%) chromium content make it reasonably resistant to pickup. However, it is unknown how the stress-relief cracks (which are, according to the product literature, characteristic of this coating) affect performance. They could trap lubricants, and this would then further reduce wear, although at the expense of some loss in braking efficiency.

The results with Stoody 103 greatly depended on hardness. The harder specimen (HRC 52-56) performed very well, but the softer specimen allowed substantial metal transfer. The very low coefficient of friction registered with the hard specimen is puzzling.

Friction was quite high with the harder Stoody 102 but metal transfer was moderate. In contrast, the soft specimen suffered severe damage.

Teledyne 258 S gave highly erratic torque traces and surface damage was severe. This does not appear to be a promising material.

Stoody 4552 was the worst coating overall. Even the harder specimen showed severe surface damage. The test on the softer specimen was invalid: immediately upon the start of rotation, local welding at the soft part of the specimen made continuing rotation impossible.

The above results confirm that both hardness and low adhesion are desirable. Harfac 6 could serve as our reference base and, if the costs are reasonable, could be tried on the full scale. If our experiments are indeed indicative of field performance, retarders coated with this material should not emit noise and wear rates should be low too. Teledyne 255 S is also promising.

It is obvious that welding up the small specimens is not easy and we sympathise with the difficulties that Crothers have been experiencing. Nevertheless, it is necessary that the specimen be built up so that a 1.25 in. diameter flat contact surface is available. The top surface of the specimen should be reasonably parallel with the bottom surface so that not more than 0.020 in. need be removed by grinding to create a perfectly parallel surface. Otherwise, milling with a carbide cutter becomes necessary, and this is both time consuming and expensive.

It is clear that some of the scatter in the results must be attributed to insufficient coverage by the coating material, at least after machining the specimens parallel. To inccrease our confidence level, it is desirable to test more than two specimens. Certainly, in the final choice for full-scale tests, it would be preferable to test at least 3 and preferably 5 ostensibly identical specimens to establish the reproducibility of results.

12 May, 1985

John A. Schey

Results of Twist-Compression Experiments

Date	Anvil material	Hardness HRC HRB	Pressure psi	Coefficient of friction	Pick-up
May 6	Stoody 102	57-60	1000	0.55	light
		79-88	1000	0.3 - 1.5	heavy
	Stoody 103	52-56	1000	0.25	v.light
		32-40	1000	0.3 - 1.5	m.heavy
	Stoody 4552	33-53	1000	0.5 - 1.8	v.heavy
		41-50	1000	0.6 - 1.2	v.heavy
	Harfac 6	37-39	1000	0.35	v.light
		32-33	1000	0.4	v.light
	Teledyne 255S	51-55	1000	0.3	v.light
		46-47	1000	0.5 - 0.6	v.light
	Teledyne 258S	45-50	1000	0.5 - 1.0	heavy
		45-51	1000	0.5 - 1.0	v.heavy

Waterloo, Ont., 12 May, 1985